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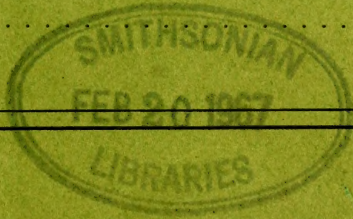
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THE HOSTS AND DISTRIBUTION OF THE ROOT WEEVILS *Hylobius pinicola* (COUPER) AND *H. warreni* WOOD IN BRITISH COLUMBIA

J. GRANT¹

Larvae of the weevils *Hylobius pinicola* (Coup.) and *H. warreni* Wood damage coniferous trees by boring in the bark and cambium of roots and root collars; injury caused by the last-named species to western white pine, *Pinus monticola* Dougl., lodgepole pine, *Pinus contorta* var. *latifolia* Engelm., and Engelmann spruce, *Picea engelmanni* Parry, has been recorded in British Columbia.

The adults climb coniferous trees and feed on the terminal shoots and needles, but cause negligible damage (Warren, 1956; Stark, 1959). Although they are mainly nocturnal (Reid, 1952), they are occasionally obtained during the day by beating the foliage of conifers over a sheet spread on the ground. As this method of sampling is commonly used in the Forest Insect and Disease Survey for assessing populations of defoliating insects, a number of incidental captures of *Hylobius* adults have been made in the period 1938-1965. This paper summarizes information relating to their hosts and distribution in British Columbia and Yukon Territory.

Hylobius pinicola and *H. warreni* are superficially similar, and until 1957 were considered as a single species, *Hypomolyx piceus* (DeGeer). Consequently, some of the records obtained in the early years of the Survey, for which the specimens can not be located, are not included in this summary. Data were available for 140 specimens; 12 were reared and the remainder were perching records. Material used in this study included two specimens of *H. pinicola* and eight *warreni* in the Canadian National Collection, Ottawa; two *H. pinicola* and 34 *warreni* in the collection of the Forest Entomology and Pathology Laboratory in Victoria, determined by Mr. D. Evans; and 29 *H.*

pinicola and 65 *warreni* in the Vernon Forest Insect Laboratory collection, determined by the writer.

Survey records of adults collected from foliage do not necessarily indicate true hosts, but since *Hylobius* weevils are flightless and somewhat sluggish, they may still be of some significance. Table 1 lists by host the specimens for which data are available.

TABLE 1—Specimens of *Hylobius pinicola* (Coup.) and *H. warreni* Wood Taken in Forest Insect and Disease Survey Collections from Coniferous Hosts in British Columbia and Yukon Territory, 1938-1965.

Host	<i>H. pinicola</i>	<i>H. warreni</i>
Douglas-fir	1	3
Fir, alpine	4	4
Hemlock, western	1	7
Larch, eastern	9	—
Pine, lodgepole	4	9
Pine, western white	—	3
Spruce spp.	12	61
Total	31	87

Trees of the cooler and moister regions have produced most *Hylobius* adults. Douglas fir is poorly represented considering the large number of collections taken from this species. No specimens have been found on ponderosa pine. Adults have been collected from late May to mid September.

The short-winged species, *H. warreni*, appears to be distributed over a large part of the Interior south of 57° latitude, and has been collected along the Coast from Rivers Inlet north to Stewart, and at Skagway, Alaska. The long-winged species, *H. pinicola*, is more northerly in distribution; it overlaps the range of *H. warreni* in central British Columbia, having been taken as far south as Horsefly and Blue River, and as far west as Smithers Landing. It has been collected as far north as Yukon Territory where samples have been taken at Dawson and Mayo. Fig. 1 shows localities where specimens have been collected.

¹ Forest Entomology Laboratory, Department of Forestry of Canada, Vernon, B.C.

In view of the intensity of surveys in southwestern British Columbia, the absence of records of these weevils in this region is noteworthy. However, it would be premature to conclude that neither species occurs in this area, until there have been extensive surveys for root damage; most records of *H. warreni* in the Okanagan-West Kootenay region are for reared specimens, and there are no perching records in some localities where there is a high incidence of root damage. An analysis of 11 years' Survey collections showed that the frequency of perching records was almost three times as great in the Prince George

Forest District and Yukon Territory as in the Kamloops and Nelson Forest districts of southern British Columbia. While this may merely reflect a higher population level in the northern areas, the scarcity of adults in collections from some southern localities where root damage is common suggests that a difference in the behaviour of the insects may be responsible for the disparity. Climatic factors in the northern regions, such as lower daytime temperatures or short summer nights may be more conducive to diurnal activity than are conditions prevailing in southern British Columbia.

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ANNOTATED LIST OF FOREST INSECTS OF BRITISH COLUMBIA PART XIII, BREPHINAE, GEOMETRINAE, STERRHINAE AND LARENTIINAE (GEOMETRIDAE)

B. A. SUGDEN¹

Members of the subfamilies Brephinae, Geometrinae, Sterrhinae and Larentiinae are not regarded as economically important forest insects in British Columbia. Only three species are known to have reached epidemic proportions: *Epirrita autumnata omissa* Harr. in 1954 on apline fir in the central Interior; *Rheumaptera* sp. in 1962 on western white birch in the Skeena River Valley; and *Operophtera bruceata* Hlst. in 1958 and 1959 on trembling aspen and willow in north-eastern British Columbia: all were of short duration.

Larvae of Brephinae differ from those of the other three sub-families in having four pairs of abdominal

prolegs regularly graduated in size. The larvae of Geometrinae, Sterrhinae, and Larentiinae have only one pair of abdominal prolegs. The body may be short and stout or twig-like with lobed sides, prominences and enlarged tubercles; or slim and tapered with a sharply bilobed head. The larvae range from green, buff, brown, grey, or black. They are solitary defoliators of conifers and broadleaved trees and shrubs. The number of collections per host is shown in brackets only when fewer than five. Pupation may occur in the litter on the forest floor or in silken cocoons in the foliage or bark crevices of trees or shrubs.

BREPHINAE

Brephos infans oregonensis Swett—*Alnus* spp., *Betula papyrifera* Marsh (2 records). Distributed throughout southern British Columbia including

¹ Forest Entomology Laboratory, Department of Forestry of Canada, Vernon, B.C.

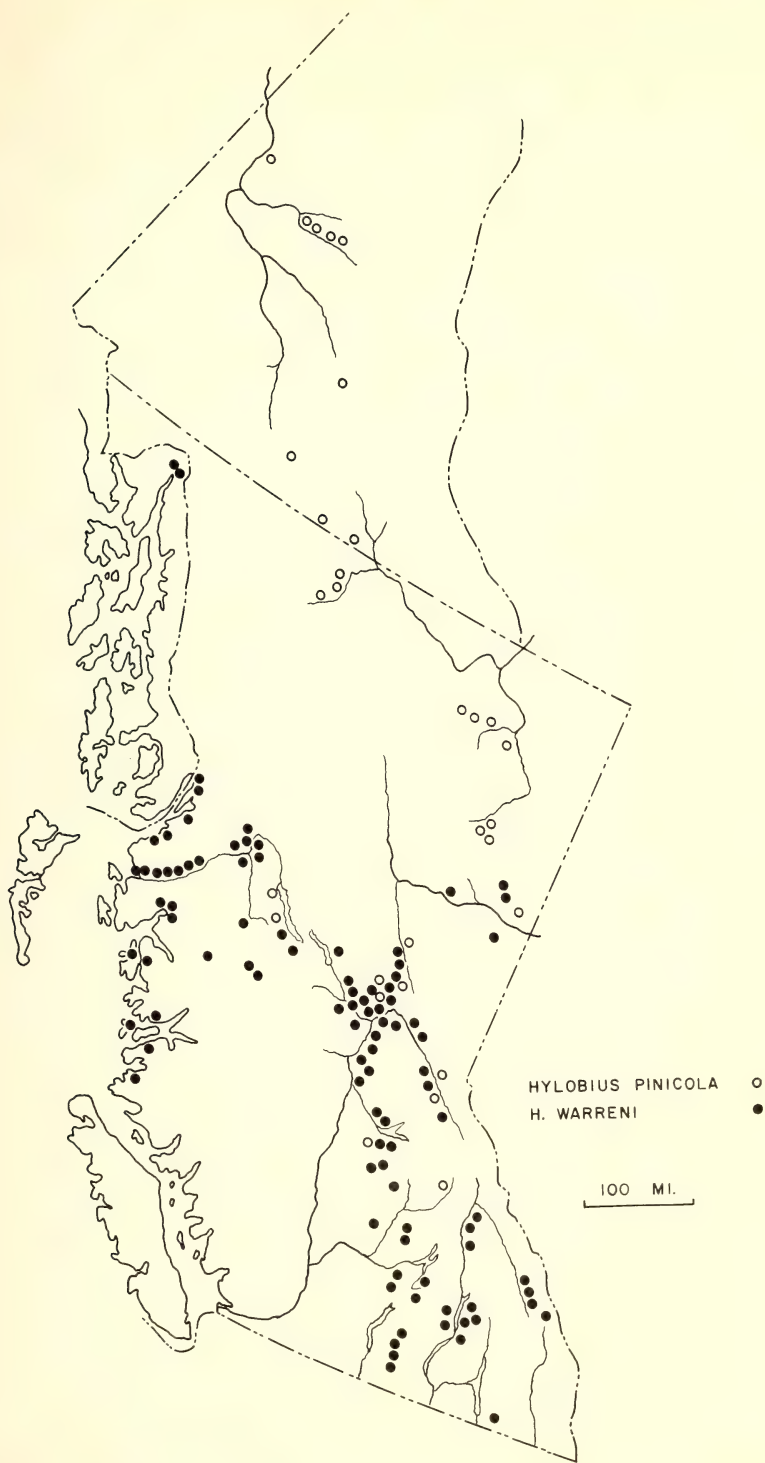


Fig. 1—Location of points where *Hylobius pinicola* and *H. warreni* have been collected in British Columbia and the Yukon Territory.

Vancouver Island; rare on forest trees.

LARVA: $1\frac{3}{8}$ inches; head immaculate light green; ocelli black; body bright green; indistinct, pale yellowish-white dorsal, addorsal and subdorsal lines; spiracles, medium buff outlined with black; broad yellowish-white subspiracular stripe; four pairs of abdominal prolegs, very small on third abdominal segment, gradually increasing on fourth and fifth to reach normal size on sixth; venter faintly marked with irregular, pale yellowish-green lines.

Leucobrephos brephoides Wlk. — *Salix* spp. (2 records), *Betula* sp. (1), *Alnus* sp. (1). Interior British Columbia from Wingdam, Peachland, Larkin, Hupel, and Mile 178 Alaska Highway; rare. **LARVA:** $1\frac{1}{8}$ inches; head medium green marked with light brown on frons and sides; ocelli, dark brown, area between ocelli, whitish; body velvety, grass green with bluish-green venter, dorsum with three pairs of fine yellowish lines; spiracles, dark brown outlined with black; broad, yellow subspiracular stripe; four pairs of abdominal prolegs, similar to *B. infans*; mid-ventral line, white.

GEOMETRINAE

Nemoria darwiniata Dyar — *Salix* spp. (3 records), *Arbutus menziesii* Pursh. (1), *Symphoricarpos racemosa* Michx. (1). Southern British Columbia, Enderby, Cascade, Vancouver and Victoria; common on shrubs but rare on forest trees. **LARVA:** $\frac{7}{8}$ inch, head small, square, medium brown; body yellowish-brown to reddish-brown with four pairs of lateral lobes on A2-5; prominent dorsal tubercles on TI and cervical shield; cone-like tubercles on TII and III and A1, 6 and 7; venter of abdomen suffused with dark brown.

Nemoria unilinearia Tayl.—*Thuja plicata* Donn. (1 record). British Columbia: Sidney: rare. **LARVA:** similar to *N. darwiniata*, but green.

Mesothea viridipennata Hlst. — *Salix* spp., *Alnus* sp. (1 record). Vanderhoof, Mud River, Wasa Lake and

Vancouver Island. **LARVA:** 1 inch; head small, granular, sharply bilobed with angles half as high as height of head, brown or yellowish-green shaded with brown; body granular, tapering to front, yellowish-green to reddish-brown; paler specimens with brown dorsal line and faintly raised addorsal lines, indistinct on TI-III; dorsal and addorsal lines less conspicuous on dark specimens; two prominent addorsal tubercles inclined toward head on TI; cervical shield tapering to a point; dark specimens with subspiracular area and venter dark reddish-brown; pale pinkish ventral line; A2-5 on pale larvae marked with reddish-brown subspiracular spots, bases of prolegs reddish-brown; venter immaculate.

STERRHINAE

Cosymbia pendulinaria Gn.—*Betula* spp. *Alnus* spp. Throughout British Columbia; common. **LARVA:** 1 inch; head small; pale yellowish-buff heavily marked with brown or pale tan, pale vertexal lines; body (two color phases with intermediates): (a) pale green with indistinct white dorsal and subdorsal lines, usually with brown spot anterior to spiracle on A1; subspiracular area of abdomen marked with pale greyish-brown; venter immaculate: (b) dorsum irregularly mottled with contrasting patches of brown, yellow, white and reddish-orange; A1-6 with oblique lateral stripes of dark brown and pale yellowish-buff; dark brown or black spot anterior to spiracle on A1; venter mottled with shades of brown; ventral line on A1-5 irregular pale yellowish green: (c) intermediates, pale green; dorsum lightly marked with shades of brown; spot anterior to spiracle on A1 usually brown or tan; venter mottled with brown and tan; yellowish-green, irregular ventral line.

Cosymbia dataria Hlst. — *Quercus garryana* Dougl. Southern Vancouver Island; rare. **LARVA:** 1 inch; head small, tan; body similar to dark phase of *C. pendulinaria*.

LARENTIINAE

Nyctobia limitaria Wlk. — *Picea glauca* (Moench) Voss., *P. engelmanni* Parry, *P. sitchensis* (Bong.) Carr., *P. mariana* (Mill.) BSP., *Tsuga heterophylla* (Raf.) Sarg., *Pseudotsuga menziesii* (Dougl.), *Abies lasiocarpa* (Hook) Nutt., *A. amabilis* (Dougl.) Forb., *A. grandis* (Dougl.) Lindl., *Thuja plicata* Donn., *Larix occidentalis* Nutt., *Pinus contorta* Dougl., *P. monticola* Dougl. (3 records), *Taxus brevifolia* Nutt. (1). Throughout British Columbia; common south of latitude 56°. LARVA: 1½ inches; head medium green, moderately retractile; body green, subdorsal lines pale green or yellowish-green; subspiracular stripe, pale yellow or yellowish-white; ventral line whitish or greenish-white.

Cladara atroliturata Wlk. — *Alnus* spp., *Betula* sp. (1 record). Southern interior of British Columbia; rare. LARVA: 1 inch; head velvety green; body slender, immaculate, velvety green, small anal tubercles; venter pale bluish-green.

Lobophora simsata Swett — *Salix* spp., *Alnus rubra* Bong. (2 records), *Populus tremuloides* Michx. Vancouver Island, Queen Charlotte Islands, central and southern coastal regions of British Columbia; rare. LARVA: ⅞ inch; head small, light green; body short, smooth, light green, light yellow subdorsal lines; small anal tubercles; subspiracular area light yellowish-green; venter green, paler than dorsum.

Lobophora magnoliatoidata Dyar — *Salix* spp. (3 records), *Populus tremuloides* (1). Chilliwack, Vernon, Nelson and Donald Landing; rare. LARVA: ⅞ inch, similar to *L. simsata*.

Operophtera bruceata Hlst. — *Populus tremuloides*, *Salix* spp., *Betula* spp., *Alnus* sp. (1 record). Throughout interior British Columbia; common. LARVA: ¾ inch; head small, pale green, immaculate, or marked with dark grey; body stout, pale green; yellow subdorsal lines; dorsum on some specimens marked with grey; supra- and subspiracular lines pale yellow, less distinct than subdorsal

line; some with grey or blackish subspiracular markings; venter immaculate, pale green.

Operophtera occidentalis Hlst. — *Populus tremuloides*, *P. trichocarpa* Torr. and Gray (1 record), *Salix* spp., *Acer* spp. (2), *Quercus garryana* (2), *Alnus rubra* (1). Southwestern, central coastal regions of British Columbia, occasionally common. LARVAE: ¾ inch; similar to *O. bruceata*; some specimens also with blackish markings.

Epirrita autumnata omissa Harr. — *Tsuga heterophylla*, *T. mertensiana* (Bong.) Carr., *Abies lasiocarpa*, *A. amabilis*, *A. grandis*, *Picea engelmanni*, *P. glauca*, *P. sitchensis*, *Pseudotsuga menziesii*, *Thuja plicata*, *Pinus contorta* (2 records), *Larix occidentalis* (1), *Betula* spp., *Alnus* spp. Throughout British Columbia; common; an infestation of short duration recorded in 1954 near the Nation River Project Road. LARVA: 1¼ inches; head small, pale green flecked with brown on vertex and sides, some immaculate; body velvety green, dark olive green dorsal and lateral lines, narrow yellowish-green lines along inner side of laterals; whitish subspiracular stripe continuing onto anal plate; some specimens without dark dorsal and lateral lines; venter pale whitish or pale bluish-green.

Epirrita pulchraria Tayl. — *Tsuga heterophylla*, *T. mertensiana* (1 record), *Picea sitchensis*, *P. glauca*, *Abies amabilis*, *A. lasiocarpa*, *Pseudotsuga menziesii*. Western British Columbia south of 56° latitude; common in coastal regions but rare in the Interior; two specimens taken in flight at Blair Lake near Falkland represent the only records from the south central Interior. LARVA: 1¼ inches; head small, pale green; body "uniform, clear apple green with two wide, white subdorsal lines which continue around the anal margin." (Personal communication, D. Evans, Dept. of Forestry, Victoria, B.C.).

Triphosa haesitata Gn. — *Rhamnus purshiana* DC., *Quercus garryana*. Southwestern British Columbia; com-

mon; one record southern Interior. LARVA: 1 inch; head tan; "Body stout, dull lime green with fine, light addorsal, lateral and wide yellow spiracular lines; tan spiracles." (Personal communication, D. Evans, Department of Forestry, Victoria, B.C.).

Hydria undulata Linn.—*Salix* spp., *Populus tremuloides*. Central to southern British Columbia; rare. LARVA: 1¼ inches; head tan; body smooth, medium olive green, narrow light addorsal and subdorsal lines; anal shield tan marked with brown; supraspiracular area dark brown; thoracic legs dark brown; posterior of anal prolegs marked with brown; venter yellowish-green.

Lygris destinata Moesch. — *Abies lasiocarpa*, *Tsuga heterophylla* (2 records), *Alnus* sp. (1), *Rhododendron albiflorum* Hook. (1). Central to southern British Columbia; rare. LARVA: 1¼ inches; head small, pale buff marked with dark brown, pale buff or whitish-buff line bordering upper side of ocelli; body slim, ochraceous, marked with dark brown, leaf-brown and pink; pale setal bases; fine pale addorsal lines on TI-III extending to apex; TII and III swollen lateral to TII with dark brown or blackish oblique stripe; pale inverted V pattern on A1-8, dark brown band on dorsum of A6 extending obliquely to venter; sides of anal prolegs leaf-brown, with a pale yellowish-white vertical stripe; irregular ventral line, dark brown alternating reddish-brown; venter banded alternately with leaf-brown and whitish-buff.

Lygris xyliana Hlst.—*Salix* spp., *Alnus* spp., *Tsuga heterophylla*, *Betula* spp., *Malus* spp., *Pinus monticola*, *Pseudotsuga menziesii* (1 record), *Sorbus sitchensis* Roem. (1). Throughout British Columbia; uncommon. LARVA: 1¾ inches; head small, pale golden-yellow with pale yellowish-brown markings; body slim, pale yellowish-orange finely maculated with pink; setal bases pale; TII wider than TI and III and marked with a leaf-brown band extending diagonally to

venter; small leaf-brown middorsal spot located centrally in an elliptical patch caudad on A1-5, A1-5 banded with brown extending to venter; paler on A1 and 2, side of anal proleg with a fine dark brown vertical line; venter of A1-5 banded with brown; pale yellowish-white between abdominal and anal prolegs.

Plemyria georgii Hlst.—*Alnus* spp., *Salix* spp., *Betula* spp., *Cornus stolonifera* Michx. (3 records), *Acer glabrum* Torr. (1). South of 57° latitude in British Columbia; uncommon. LARVA: 1 inch; head small, pale green; body very slender, smooth, pale green with yellow subdorsal lines; two whitish, prominent, pointed projections on upper posterior of anal prolegs; thoracic legs pinkish to reddish on some specimens; venter, immaculate.

Dysstroma truncata Hufn. — *Larix laricina* (DuRoi) K. Koch (2 records), *Alnus* spp. (2), *Picea* sp. (1). Miles 69 and 290 Alaska Highway; rare. LARVA: 1 inch; head small, yellowish-green; body slender, green, indistinct whitish subdorsal lines, reddish lateral lines; small points on anal shield; venter immaculate, pale green.

Dysstroma citrata Linn. — *Tsuga heterophylla*, *Picea sitchensis*, *Pseudotsuga menziesii*, *Alnus* spp., *Salix* spp. A general feeder, found occasionally on other broadleaved trees and shrubs south of latitude 56° in British Columbia. LARVA: 1 inch; similar to *D. truncata* but rarely with reddish lateral lines.

Dysstroma ethela Hlst. — *Ribes* sp. (1 record). Anarchist Mountain. LARVA: 1 inch; similar to *D. truncata* but without reddish lateral lines. Body minutely spinulose with white setae.

Dysstroma formosa Hlst. — *Ribes* spp. Southern Interior; uncommon. LARVA: 1 inch; head small, yellowish-green; body slender, spinulose, pale green, minute whitish tubercles, in rows, form the subdorsal lines; indistinct, whitish lateral lines; small, whitish projections on upper poste-

rior side of anal proleg; broken yellowish-white ventral line.

Dysstroma sobria Swett — *Picea sitchensis*. Coastal British Columbia; rare. LARVA: unknown.

Thera otisi Dyar—*Juniperus communis* L. South of latitude 54°, interior British Columbia; uncommon. LARVA: $\frac{3}{4}$ inch; head pale greenish-tan; body pale green, pale bluish-white addorsal lines, greenish-white subdorsal stripes extending onto anal plate, greenish-white subspiracular stripes bordered above with a pink to reddish, broken line on TI-III and A1-3; thoracic legs pink or marked with pink; venter unmarked.

Stamnoctenis morrisata Hlst.—*Juniperus scopulorum* Sarg. Southern interior of British Columbia and Vancouver Island; common in small numbers. LARVA: 1 inch; head retractile, pale greenish-tan; body green with black setal bases; dark green dorsal line; irregular white subdorsal stripes, narrower on thorax but accentuated on posterior of each abdominal segment; posterior of A2-7 marked with a short reddish-brown line between the spiracles; posterior to subspiracular A1-7 marked with yellowish-buff and white; lower half of abdominal prolegs pale reddish-brown; subspiracular area of thoracic segments marked with white; diagonal reddish-brown markings, fading towards venter, on A1-8, lacking on A1 in some specimens; venter of abdominal segments indistinctly banded with yellowish-green.

Rheumaptera hastata Linn. — *Alnus* spp., *Betula* spp., *Salix* spp. South of latitude 55° in British Columbia; common. LARVA: 1 inch; head small, medium brown, marked on sides and front with dark brown; body stout, skin smooth, black; subdorsal lines formed by two rows of small, irregularly shaped, creamy-white spots, subdorsal lines lacking on some specimens; cervical shield dark brown; anal plate medium brown; broken, creamy-white to buff, supraspiracular and subspiracular stripes, coalesced

around the spiracles on TI and A1-3 on some but indistinct on other specimens; subventral setal bases outlined with creamy-white; band of creamy-white on lower abdominal prolegs; A9 below anal shield creamy-white, anal prolegs creamy-white, marked anteriorly with black and posteriorly with greyish-brown bordered with pink.

Rheumaptera albodecorata Blkmre. — *Betula* spp., *Alnus* spp., *Menziesia ferruginea* Smith (1 record). South of latitude 56° in British Columbia; rare. LARVA: 1 inch; head small, orange-brown, sides and front marked with dark brown; body stout, smooth, pale yellowish-buff; medium brown, irregular dorsal line, pale brown addorsal lines and medium brown subdorsal stripe; medium brown cervical shield and pale tan anal plate; broad yellowish-buff lateral stripe; venter medium brown indistinctly banded with pale brown; lower half of abdominal prolegs pale buff; anal prolegs pale buff marked anteriorly with brown and posteriorly with pale tan.

Venusia cambrica Curt. — *Alnus* spp., *Betula* spp., *Salix* spp. Throughout British Columbia; common. LARVA: $\frac{3}{4}$ inch; head small, pale green; body stout, bright green; yellowish lateral lines extending to anal shield; some specimens sparsely or profusely marked with pink or dull red on dorsal, lateral and ventral areas.

Venusia pearsalli Dyar—*Alnus* spp., *Salix* spp., *Populus tremuloides*, *Quercus garryana* (2 records). *Cornus nuttali* Audubon (2), *Betula* sp. (1) *Populus trichocarpa* (1) *Acer circinatum* Pursh (1), *Crataegus* sp. (1). South of latitude 56° in British Columbia; common, particularly in south western regions. LARVA: $\frac{3}{4}$ inch; similar to *V. cambrica* but without pink or red markings.

Venusia duodecemlineata Pack. — *Pseudotsuga menziesii*. Vancouver Island, rare. LARVA: $\frac{3}{4}$ inch, pale green (Personal communication, D. Evans, Dept. of Forestry, Victoria, B.C.).

ANNOTATED LIST OF FOREST INSECTS OF BRITISH COLUMBIA:

PROC. ENT. SOC. B.C.

- Ross, D. A. and D. Evans. 1954. Part I—*Lasiocampidae*, *Saturniidae*, *Liparidae*. 51:40-43.
 Ross, D. A. 1954. Part II—*Laspeyresia* spp. (*Olethreutidae*). 51:44.
 Ross, D. A. and D. Evans. 1956. Part III—*Eupithecia* spp. (*Geometridae*). 52:36-38.
 Ross, D. A. and D. Evans. 1956. Part IV—*Hydriomena* spp. (*Geometridae*). 52:38-39.
 Ross, D. A. and D. Evans. 1957. Part V—*Dioryctria* spp. (*Pyrilidae*). 53:10-11.
 Ross, D. A. and D. Evans. 1957. Part VI—*Plusia* (*Syngrapha*) spp. (*Noctuidae*). 54:18.
 Ross, D. A. and D. Evans. 1957. Part VII—*Apatela* (*Acrionicta*) spp. (*Noctuidae*). 54:16-17.
 Ross, D. A. and D. Evans. 1958. Part VIII—*Semiothisa* spp. (*Geometridae*). 55:40-41.
 Ross, D. A. and D. Evans. 1959. Part IX—*Caripeta* spp. (*Geometridae*). 56:15.
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 Sugden, B. A. and D. A. Ross. 1963. Part XI—*Papilio* spp. (*Papilionidae*). 60:17-18.
 Sugden, B. A. 1964. Part XII—*Boarmiini* and *Melanolophiini* (*Geometridae*). 61:36-39.

NOTES ON THE BIOLOGY OF THREE ARCTIID MOTHS FROM
BRITISH COLUMBIA

HELMUT P. KIMMICH

Neoarctia brucei H. Edw.

N. brucei is not listed by Jones (1951). It inhabits the southern slopes of alpine meadows in Manning Park at altitudes of about 6,500 feet, and is rare in collections. With a wingspan of 35 mm, this is a moth of striking beauty having black forewings with broad rose coloured grid lines and bright red hindwings with heavy, broad spots, confluent at the outer margins.

After hibernation the small larvae appear in June, at first on bare spots around trees and later mostly along the edges of still remaining snow patches. There, with maximum exposure to the warmth of the sun, they rest in a curled position on the bare ground or walk swiftly, covering considerable distances in search of their favorite food plants: the tender sprouts and shoots of *Senecio*, mountain grass, phlox, and buds of *Vaccinium*. By the time the last snow patches have melted, the larvae have hidden in the thickets of fast-growing alpine flora. They reach maturity before the leaves of the dwarf *Vaccinium* turn dark green. The moth emerges in July after two weeks in the pupal stage. Flight and copula take place at dusk.

The female lays between 80 and 120 eggs in batches. The ovum is spherical and gold coloured. Hatching follows 10 days after oviposition and there are six larval instars. At maturity the larva measures 30 mm, the head is small and black, the body and tubercles are black, dotted with shiny spots, visible in the reflection of light, and with soft tufts consisting of black and white hairs, the white ones more numerous at the sides. The dorsum is adorned with tufts of pale olive green.

The pupa is 17 x 5 mm, with the wingcases translucent reddish, the mobile cremaster dusted with slate blue, the segments blackish and bordered, and the head furnished with inconspicuous bristles. It rests in a light cocoon of plant material.

Caged caterpillars are reluctant to accept substitutes for their native food plants. Taking only mature larvae and presenting them a variety of wild, native plants is critical for successful rearing. The picked plants preserved in tightly closed jars and kept cool, will prove satisfactory. However, a new brood emerging in confinement can be successfully reared on *Taraxacum* if they have not hibernated. Ample space, artificial

heat and adequate moisture are essential. A second brood in the same season may even be partly brought to pupation. Creating conditions similar to those found under a cover of snow, will give modest success with a brood in hibernation. The box used for overwintering should not contain anything of plant origin because of the disastrous effects of moulds and fungi. To induce copulation in captivity, the breeder must use his field observations of the impetuous flight of the male and of the climatic conditions at the time of mating. The provision of cages with ample space for flight, cold air at dusk, and a breeze in the evening will reproduce some of the factors for mating. The male is able to enter more than one copulation.

A tiny parasitic wasp of 2 mm wingspan takes advantage of the conspicuous exposure of resting larvae to reduce the overwintered stock drastically every year.

Apanteles elongata Stretch

This species is listed as No. 1050 by Jones (1951). It was identified in Ottawa after its discovery several years ago in Manning Park. *A. elongata* and *N. brucei* have similar life histories and share the same habitat.

The male, with a wingspan of 30 mm, has black forewings with fine white grid lines which sometimes are partly missing, and the typical "W" at the outer margin. The hindwings are black also with a circular black spot in the discoidal cell bordered by a broad white band. Below the cell a distinct white line extends from the thorax towards the outer margin, its widened end sometimes connected with the aforementioned black spot. The abdomen is black with an ochraceous stripe on both sides. Some males exhibit mutations with broad white grid lines in the discal area. Such aberrant males have completely black abdomens. The white pattern on the hindwings of the male is typical and dominant, but an ochraceous pattern occurs rarely.

The female has forewings like those of the male, but the hindwings are ochraceous with broad black spots at the outer margins, sometimes confluent. The line extending from the thorax into the limbal area is black. Females showing the typical geometrical pattern on the hindwings are quite rare. Mutations, showing black hindwings with only a shade of ochraceous left and forewings with a white broad blotch in the discal area also occur.

In nature the larvae are found associated with *N. brucei* and can be reared in the same way. They are more agile but less exposed and better camouflaged. This may explain why they were parasitised less than the larvae of *N. brucei*. A brood in confinement, unlike *N. brucei*, will not reach maturity without hibernation.

The ovum is spherical, pale yellow and much smaller than that of *N. brucei*. The female produces up to 200 eggs, which are laid loosely and apparently casually.

The mature larva measures 30 mm. The head and body are black, the tubercles black and dotted with tiny white spots reflecting the light; the tufts are rough and short, black on the dorsum, maroon at the sides. The dorsal line is comprised of lines and spots in an alternate pattern of white, brown or ochre. Often the dorsal line is missing.

The pupa is dusted with slate blue, the seams black, the cremaster mobile, the head with short black bristles, more accentuated than in *N. brucei*.

Parasemia (Hyphoraia) parthenos Harr.

This superb Arctiid is distributed throughout the Northern Atlantic States and Canada. Its occurrence in British Columbia is sporadic and apparently restricted to small localities in light, damp forests with underbrush, often hundreds of miles apart. Wherever sighted, the number of specimens appears always very limited. Undoubtedly this moth is rare

and probably permanently endangered by civilization. It should be high on the list of insects to be protected in nature. The moth survives only in undisturbed environment with ideal and balanced conditions.

By the end of June it is on the wing, but only in *even*-numbered years, which indicates a two-year life cycle. Males will come to a light, but not females which appear to avoid any kind of trap. In the course of obtaining breeding material, I have sacrificed many night hours in vain at different places and have never seen a female landing in the vicinity of the light. The number of males appearing never exceeded five, an indication of its scarcity and limited number. On June 30, 1962, near Westbank, B.C., a female was found by accident, resting on a doorstep. On July 1 it laid about 80 eggs in a mass. The eggs were white, dull, and globular, slightly flattened.

In ten days the larvae hatched and were kept in small closed jars with perforated lids, exposed during daylight to artificial heat. Since all known breeding places had abundant growth of *Symphoricarpos*, this shrub was tried as a food plant, and was very successful.

By August 22 in the VIIIth instar, about 70 per cent of the larvae had reached maturity without further loss. Thus one hibernation was eliminated, thanks to artificial heat and adequate moisture in the jars. The mature larvae continued to feed until they refused further food in the very late fall.

Hibernation took place in a box-like container outdoors under a roof. Inside was sterilized moss, which was moistened from time to time. However, most of the larvae died during the winter and early spring until finally only three remained to pupate in late spring. These also perished. The failure was probably caused by uncontrolled moisture which allowed fungi and mildew to grow. Obviously conditions were not equivalent to those in nature.

Extensive search for larvae in the vicinity of breeding places did not produce results, since these feed at night and are well hidden during daylight. The only remaining chance was to watch for mature larvae in late fall when they travel in search of hibernation sites. Occasionally they cross roads in full sunlight. In 1965 ten mature larvae were found in this way, which were fed with leaves of *Symphoricarpos* until they rolled up for the winter. At maturity the larvae were 40 to 45 mm long, with head and body black, hairs long and black, the tubercles greyish white and inconspicuous.

Larvae of this family spend a great part of their lives under a cover of snow, and they have an exceptional need for moisture. But direct moisture seemed to be deadly, producing fungi, particularly on the prolegs. The container for hibernation, consisted of two parts: the upper part covered with curtain fabric with a perforated bottom; the lower part a reservoir for water. The perforated bottom was covered with a layer of cotton fabric and two rocks were placed on it and covered with a double layer of cotton fabric to leave cavelike spaces beneath. The whole assembly was sheltered by an A-frame with an impervious cover and placed outdoors under spruce trees and close to a stump covered with shrubs. The layers of fabric were moistened every two days except in the snow season.

At the end of February, 1966 one larva was found dead, a victim of fungus. In March several more succumbed. Temperature changes in early spring caused frequent interruptions of the winter sleep. At the end of March the remaining three larvae became active and prepared for pupation by emptying their intestines. On April 1 they began to spin loose cocoons, and on April 5 one larva finished its cocoon of mixed silk and hairs, choosing the curtain fabric as a suitable place. Two others spun

cocoons between the rocks under the double layer of fabric. On April 16 a pupa could be seen in the cocoon under the curtain fabric. It was 27 mm long, black and shiny. A female emerged on June 1, after six weeks pupation. A male emerged from a

cocoon between the rocks on June 11. The third pupa was killed by mildew. The moths emerged 10 days earlier than those observed in nature, a sign that the hibernation place was too warm and the ambient air too dry. None of the larvae reared was parasitised.

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RECORDS OF TICK PARALYSIS IN LIVESTOCK IN BRITISH COLUMBIA

J. D. GREGSON¹

ABSTRACT

Reports of 189 outbreaks of tick paralysis in livestock in British Columbia are tabulated with regard to distribution, the kind and number of animals involved, the annual incidence of paralysis, and the dates and sizes of the major outbreaks. The disease is most prevalent in the western half of the interior dry belt where there have been apparent peak years of cases. The recorded totals are in excess of 2010, 1849, 9, and 13 for cattle, sheep, horses, and dogs, respectively. Most of the loss from the disease results from the extra manpower needed to care for affected animals, reduced animal condition, and disuse of otherwise valuable pasture.

Almost every year since its inception in 1928, the entomology laboratory at Kamloops, B.C., has received word of cases of tick paralysis in livestock and humans in this province. Since the published records refer only to 11 out of some 190 outbreaks of the disease in livestock, it is felt that more information should be made available from data in this laboratory's files.

Tick paralysis was first recognized as a disease in North America when Todd, in 1912, accumulated case histories of the effects associated with tick bites in humans and differentiated the symptoms from those of Rocky Mountain spotted fever. Hadwen (1913) associated the disease with a condition observed in the vicinity of Keremeos, where for three years a farmer had up to 300 of his sheep affected by a form of paralysis. Hadwen proved experimentally that the disease was caused by the bite of *Dermacentor venustus* Banks (= *D. andersoni* Stiles). His theory that a toxin caused the symptoms remains unchallenged.

Other than Bruce's (1920) warning to ranchers of tick paralysis, there are no further references to outbreaks until Bruce's publication in 1922. In this, he records witnessing an outbreak at Vavenby where Moilliet had 300 sheep affected out of a band of 400. Subsequent unpublished references to this rancher indicate that up to 1928 as many as 10% of his flock of 1300 were sometimes paralysed.

In 1928, at the request of the B.C. ranching industry, a laboratory was established at Kamloops for the study

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of insects affecting livestock. After this date all records of tick paralysis appear in the laboratory's files and unpublished monthly reports. These have been the source of most of the figures presented here.

Concerning the validity of these records, it must be noted that only occasionally have instances of paralysis in livestock been fully and officially verified. The symptoms are so well known to the stockman that his first thought is for his animals, and only after they have been "de-ticked" does he trouble to report the occurrence, and not always then. Frequent-

ly the information trickles in second-hand a year or more later. Nevertheless, because the symptoms are not likely to be confused with other illnesses, there is usually little doubt of the authenticity of cases witnessed and reported by ranchers.

The size of an outbreak is often more questionable; a distraught rancher tends to exaggerate his losses. Compensating this in the overall picture is the fact that many instances of tick paralysis never are recorded. Indeed, herders have frequently been reticent in reporting their troubles even to their employers for fear of reprisals for negligence.

TABLE 1—Number of livestock and humans paralysed annually in British Columbia by ticks as reported to the Kamloops laboratory since 1900.

Year	Cattle	Sheep	Horses	Dogs	Totals	Reports	Humans
to 20	13	385*			398*	6	±80
20-28	22	375	2		399	7	+80
28	*	130			130*	2	6
29	4	26*			30*	6	9
30	101	24			125	5	11
31	2	20	1	1	24	5	
32	2	20*			22*	3	5
33	2*	22			24*	5	1
34	29	1*			30*	5	4
35	200	13		5	218	12	4
36	15	103	1		119	7	
37	22	2*			24*	5	1
38	10	211			221	8	4
39	20	2*			22*	4	7
40	32			2	34	4	1
41		1	1		2	2	1
42	25	16*			41*	4	2
43	16	*	1		17*	4	
44	491*		3		494*	11	2
45	34				34	4	3
46					0	0	
47	3	*			3*	2	2
48	70				70	2	4
49	1				1	1	4
50	58*	50			108*	7	
51	103	341			444	21	
52					0	0	1
53	*				0	1	8
54	1	100			101	2	7
55	30				30	1	2
56					0	0	2
57	385*				385*	10	2
58	1				1	1	1
59	23				23	3	1
60					0	0	3
61					0	0	1
62	1	3		2	6	4	7
63	1				1	1	5
64	263*	4			267*	19	3
65	30			3	33	5	2
Totals	2010	1849	9	13	3881	189	276

* "several" cases. These are not entered in the totals.

Human cases are well documented in the Kamloops files since 1928, but prior to that date the records are obscure and there are possibilities of duplication.

In this paper the 189 single and multiple records of tick paralysis in livestock are tabulated in three ways. Fig. 1 illustrates their distribution and the kind and approximate numbers of animals involved. Table 1 lists, separately and together, the annual totals of paralysed cattle, sheep, horses and dogs, and also the annual incidence of paralysis as recorded from separate reports, either single or grouped cases. Human cases have been included to give an overall picture of tick activity. Table 2 lists those outbreaks which exceeded 20 paralysed animals.

Reference to these tabulations, with details in the original reports, permits some speculation regarding the frequency and distribution of tick paralysis as it affects livestock. However, in dealing with a disease as enigmatic as this one (Gregson, 1962) caution must be taken not to be misled by false interpretations for it will be apparent that to evaluate properly any one aspect, the whole picture must be considered. Since the main purpose of this paper is to list the incidence in livestock, other aspects of the disease will not be discussed.

The distribution of tick paralysis in livestock, with the exception of two known outbreaks, appears to be confined to the western half of the interior dry belt. The largest outbreaks

TABLE 2—Outbreaks of tick paralysis in B.C. since 1911, involving more than 20 head of livestock.

Date	Locality	Positions*		Cattle	Sheep	No. exposed to ticks	Paralysed	Died
1911	Keremeos	49°N	119°W		x	900	46 +	46
1912	Keremeos	49	119		x	900	334	90
1920	Vavenby	51	119		x	400	300	—
1927	Similkameen	49	119		x	—	40 +	40
1928	Vavenby	51	119		x	1300	10% yr	few
1929	Blackpines	50	120		x	350	20/day	few
1930	Douglas L.	50	120	x		900	100	65
1930	Stump Lake	50	120		x	—	10-15/day	—
1931	Copper Cr.	50	120		x	700	20 +	20
1932	Falkland	50	119		x	180	35 +	35
1935	Quilchena	50	120	x		638	200	26
1936	Wolf Cr.	49	120		x	1000	100	—
1938	Pinantan	50	120		x	1700	90	12
1938	Jaffray	49	115		x	—	100 +	100
1940	Scheidam Fl.	50	120	x		200	26	5
1944	Merritt	50	120	x		—	40	12
1944	Quilchena	50	120	x		1230	400	50
1944	Douglas L.	50	120	x		—	42 +	42
1948	Big Creek	51	122	x		2000	50	several
1950	Merritt	50	120	x		—	40	3
1950	Pritchard	50	119		x	300	50	1
1951	Quilchena	50	120	x		800	30	3
1951	Penticton	49	119		x	—	20 +	—
1951	Barnhartvale	50	120		x	700	270	7
1954	Barnhartvale	50	120		x	—	100	—
1955	Douglas L.	50	120	x		400	30	2
1957	Stump Lake	50	120	x		118	32	7
1957	Douglas L.	50	120	x		700	320	30
1964	Alkali L.	51	122	x		300	22	7
1964	Dog Cr.	51	122	x		650	± 90	3
1964	Farwell Can.	51	122	x		250	± 60	13
1964	Copper Cr.	50	120	x		400	30	—
1965	Chimney Cr.	52	122	x		250	28	—

* According to 1953 Gazetteer of Canada; B.C. Co-ordinates given at S.E. corners of the geographical quadrilaterals.

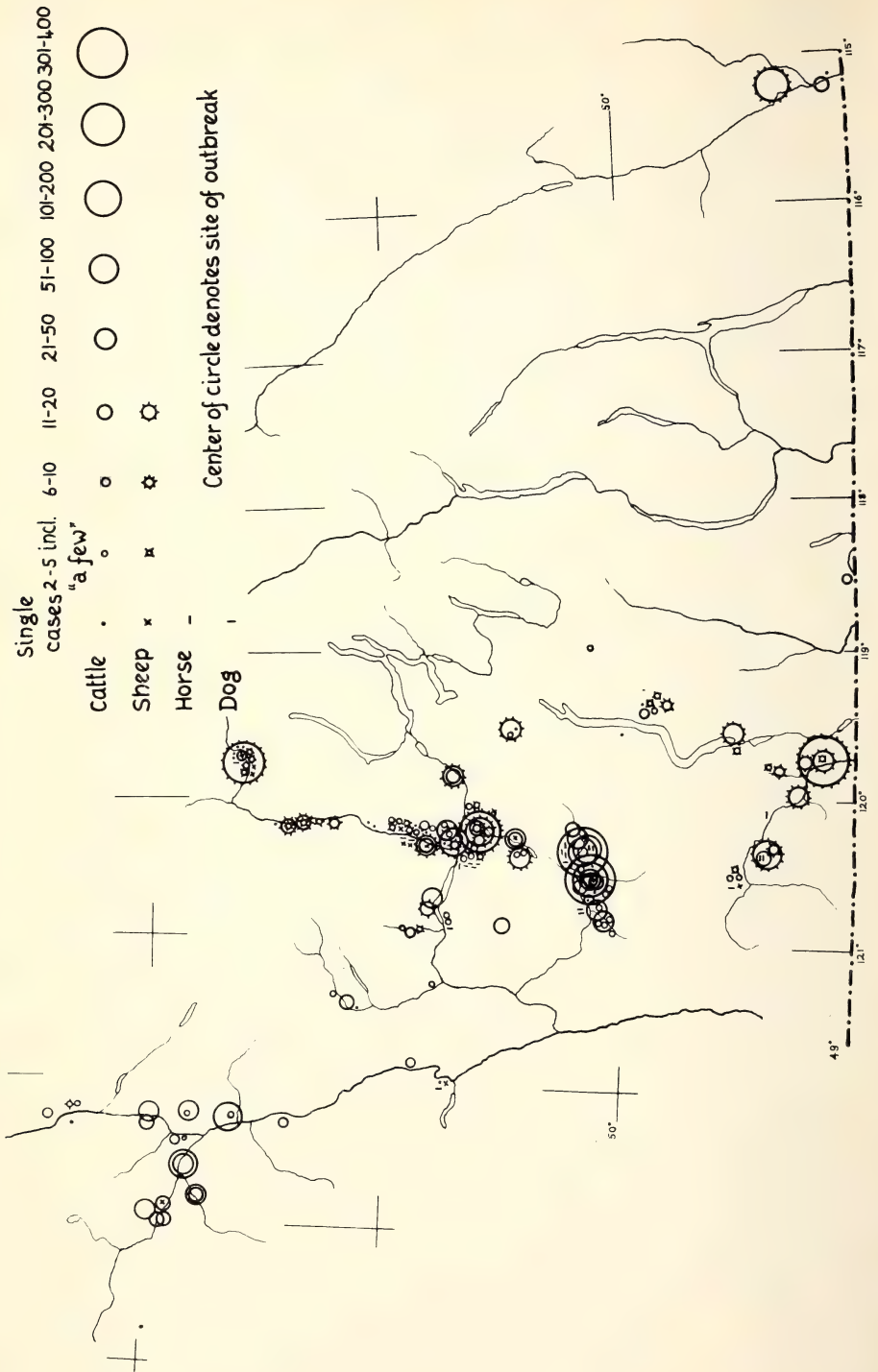


Fig. 1—Occurrences of tick paralysis in south-central British Columbia from 1900 to 1965.

occur in the best areas for ranching, in the vicinity of Keremeos, Princeton, Nicola, Kamloops and Vavenby (Hearle, 1933; Moilliet, 1937; Gregson, 1958). Smaller, more localized outbreaks have been recorded at points along the Fraser River trench from Lillooet to Macalister and up the Chilcotin River to Alexis Creek. Others have appeared at Mamette Lake, Upper Bonaparte, Chase, Falkland and Kelowna.

The paucity of cases in the Kootenay district may partly be due to the fact that only about 15% of the beef cattle industry is in that area. Nevertheless, there are enough animals and ticks for a paralysis potential. Of interest is the fact that since 1928, 25% of the human cases in B.C. have occurred in this region. Conversely, there is only one human record in the vicinity of Nicola Lake where a total of more than 1000 cattle have been paralysed. Host density is obviously a factor in the incidence of paralysis but presumably not the only one. Ticks east of the Rocky Mountains produce paralysis rarely, if at all.

Besides the apparent distributional variation in tick virulence, there is the possibility of seasonal variation, resulting either from tick activity or their feeding habits. Ranchers are often heard to say that there are "bad tick years." One sheepman believed that extremes in spring temperatures made the ticks "hungrier and deadlier." Whether or not there are such variations in tick virulence, Table 1 shows that some years such as 1935, 1944, 1951, 1957 and 1964 are worse than others for livestock infestations. Not only were there major outbreaks of paralysis during these years, but also there were more than the average number of separate outbreaks. A questionnaire solicited much of this information in 1951, but questionnaires were sent out also in 1939, 1955 and 1965. It is perhaps significant that the incidence of human paralysis is not appreciably higher during years of heavy livestock paralysis.

Human exposure to ticks would be expected to be less variable than that of livestock and may thus indicate that variations in the livestock records are more or less determined by movements of the cattle. During years of hay shortage special advantage is taken of warm, tick-infested hillsides for early spring grazing; this might further coincide with a year of high tick activity. When conditions of a particular year force this practice upon many ranchers, there may be a high incidence of paralysis, often in new areas. Such was the situation in the Fraser River trench in 1964. Changing ranching practices such as the decline in sheep populations, or avoidance of tick-infested areas following an outbreak of paralysis, are also responsible for annual fluctuations of this disease.

One often hears that ticks are on the increase, or that they were originally brought in on livestock. Dr. L. Guichon, pioneer rancher in the Nicola valley from before 1890, was of the latter opinion and did not become aware of ticks as a pest until after 1920. Parks, of Cache Creek, saw ticks for the first time in 40 years in 1928; Lees, at Hanceville since 1913, noticed ticks there first in 1916, then further west at Alexis Creek in 1937; Cotton, of Riske Creek, reported in 1941 that ticks were the worst in the 43 years of his ranching experience and that he had had no ticks at first; Collett, of Merritt, had his first tick trouble in 40 years during 1945; Davis, of Mamette Lake, had his first trouble in 13 years during 1957; Cordonier reported ticks in 1950 for the first time during his 30 years of ranching at Barnhartvale. Although the first published records of paralysis are those appearing along the B.C.-U.S. border, there is no reason to suppose that *D. andersoni* was introduced into Canada from the south. Indeed, correspondence from Moilliet of Vavenby and Johnson of Alkali Lake, report paralysis in cattle on their relatively northern ranches in 1907 and 1903 respectively. It is probable that tick

populations have merely increased following the introduction of livestock into already infested areas.

The incidence of paralysis in livestock is greatest between the 10th and 27th of April. Occasional cases occur two weeks on either side of these dates. The earliest case recorded was on February 9, 1962; the latest, June 15, 1965. Since paralysis occurs only after a tick has been feeding for 5 or more days the dates of the initial infestations would necessarily precede the recorded periods.

The ratio of paralysis in the two groups of livestock most affected has depended partly on which animals were being pastured on infested pastures. Until 1930, cases among sheep were more common; during recent years cattle have superseded sheep and have been more affected (Table

2). The recorded cases for the entire period are in excess of 2010 cattle, 1849 sheep, 9 horses and 13 dogs.

The economic aspect of tick paralysis is difficult to estimate. Definite, recorded deaths over the past 50 years are not greatly in excess of 361 cattle, 251 sheep and 6 horses, representing a value of only about \$60,000 even at present prices. Greatly exceeding this figure are the combined losses of manpower required to handle cattle during week-long outbreaks, of animal condition during recovery, and of potential pasturage unused through fear of ticks. The use of BHC during the past 18 years has helped to alleviate the hazard of paralysis. Apart from this remedy, whenever untreated stock are pastured on tick-infested ranges, there still remains the threat of large outbreaks of tick paralysis with heavy animal losses.

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A RECORD OF THE BROWN-BANDED ROACH

In 1960 specimens of the brown-banded roach, *Supella supellectilium* (Serv.) were sent from a New Westminster home. The furniture in the newly-built house had been shipped from California in a moving van within the last year and the infestation had since developed. Arrangements

were made to spray the house and the roach was controlled.

The roach has not been recorded from Canada west of Winnipeg. Mr. C. G. MacNay, Ottawa, has reported it from eastern Canadian cities.

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THE PEACH TWIG BORER, *Anarsia lineatella* ZELL. (LEPIDOPTERA: GELECHIIDAE), IN THE OKANAGAN AND SIMILKAMEEN VALLEYS OF BRITISH COLUMBIA

D. S. SARAI¹

INTRODUCTION

The peach twig borer, *Anarsia lineatella* Zell., is reported from Europe, Asia, and North America. It is present in 35 states of the U.S. (Bailey, 1948), in Ontario and British Columbia, where it is often a serious pest of peach and apricot in the Okanagan and Similkameen valleys. Almond, cherry, nectarine, plum and prune are also listed as host plants (Bailey, 1948). The larva tunnels the buds and terminal twigs and infests the fruit. The present study was intended to provide information on which to base more effective timing of insecticide applications. Some growers have had difficulty in controlling this pest.

METHODS and MATERIALS

The seasonal history was investigated from 15 May to 15 October, 1966 in peach and apricot orchards near Penticton in the Okanagan Valley and Cawston in the Similkameen Valley. The presence and activities of different stages were recorded each week and the developmental stages collected for detailed study. In the laboratory cages small vials of water plugged with absorbent cotton supplied water to the moths. The larvae fed satisfactorily on green or ripe peaches and apricots. Green fruit lasted for from 10 to 15 days, and the larvae easily re-established in fresh fruit. When mature larvae left the fruit most of them moved to the top of the cages to pupate in folds of cheesecloth; others pupated in corners or in folds of paper. Tender shoots were not satisfactory food because they wilted or died within three days. It is not known whether overwintered larvae, which feed normally on buds and shoots, can also develop on fruit. They were already pupating by mid-May.

To study adult flight patterns two U-V light traps were used, one 10 miles south of Penticton, the other five miles east of Cawston. The light was on each night from 8:00 p.m. to 6:00 a.m. The bottle under the light was partly filled with a 70% mixture of ethyl and methyl alcohols, which was emptied and replenished every fourth day. The method was impractical in that it was extremely time consuming to locate the small moths in the great number of trapped insects, but it did give some indication of the adult population levels and supported the field observations. Adults are difficult to observe in the orchards because they are small and their colouration blends into the bark. Adult emergence in orchards was noted by marking pupae and checking these regularly. The cremaster is securely attached so that the empty cases remain after the adults have emerged.

SEASONAL HISTORY

The seasonal history was the same in the Okanagan and Similkameen valleys. Fig. 1 shows the seasonal history at Penticton in 1966. Overwintered larvae which had been feeding on buds and new shoots, started to pupate by mid-May. A few larvae were still feeding, but most of them were moving downwards to the large limbs and trunks to pupate in cracks, pruning scars, or under loose bark. By 24 May almost all had pupated. The mature larva is about 13 mm long. It spins a loose, grey-white web and pupates beneath it. The pupa is 3 to 4 mm long, brown to dark brown, attached by the cremaster. Moths were first seen on 7 June and the peak of adult population was reached about mid-June.

Oviposition began within a few days of emergence of the adult and

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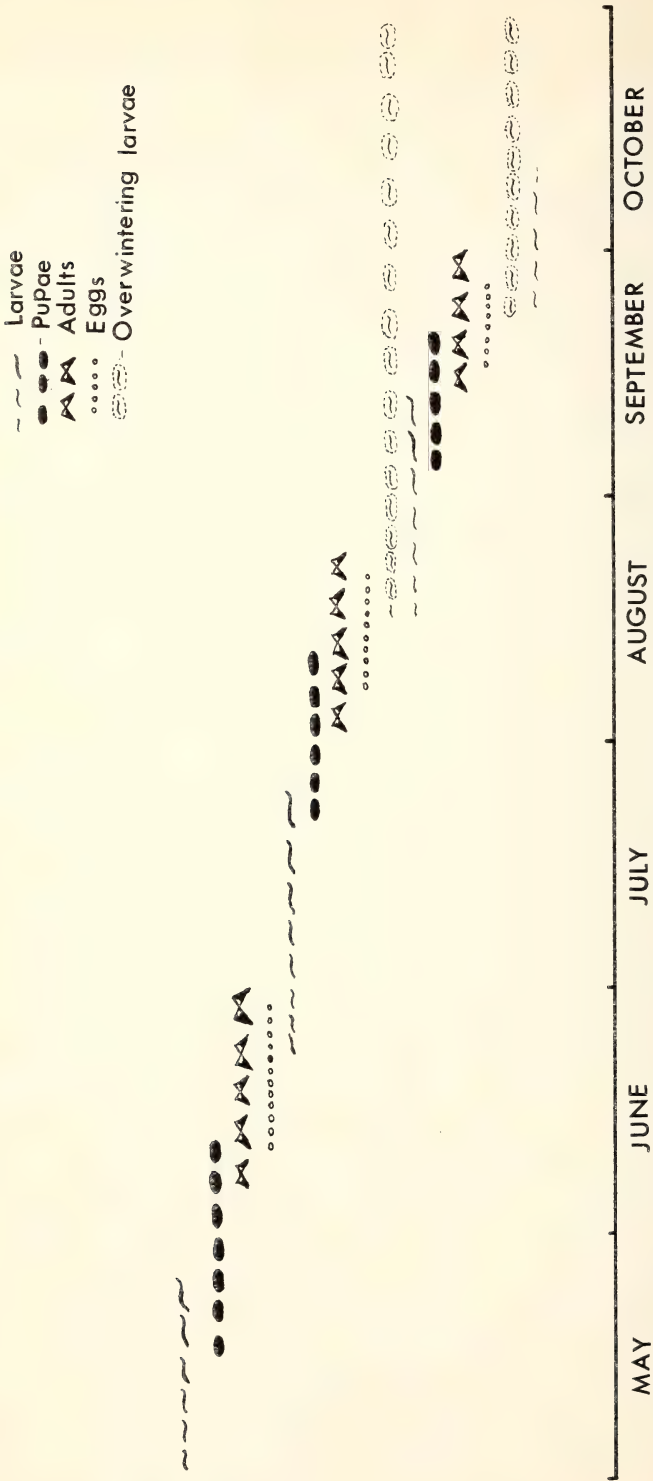


Figure 1—The seasonal history of the peach twig borer, *Anarsia lineatella* Zell. in the Penticton area of the Okanagan Valley, B.C., 1966.

continued for about two weeks. Most of the eggs were laid on the terminal parts of young shoots but some were laid on fruits. Larvae from these eggs were first seen on 22 June feeding on terminal and side shoots and leaf bases. The newly-hatched larva is about 5 mm long, light brown with a black head.

Wilted shoots caused by first-instar larvae were not noticeable since they consisted only of one or two small leaves. But by 6 July they were noticeable because the longer larval tunnels included more leaves. A wilted shoot with a larva still inside was clean, but an abandoned shoot exuded gum. Wilted shoots were fewer and damage to fruit started earlier on apricot than on peach, possibly because apricot has fewer shoots and softer fruit. Some larvae apparently fed on apricot fruit at once on hatching in late-June, whereas damage to peach fruit did not start until about mid-July. In the hard unripe fruit the tunnels were superficial, and mostly in the stem half.

Pupation began about 20 July, in cracks in the bark or curled bark, under loose bark or even on the surface of the fruit. The larvae did not spin a web. Adults emerging from these pupae were first seen on 3 August, and were in maximum numbers by 10 August. They were easily seen in heavily infested orchards resting on trunks, branches and fruit. They were seen more often on apricot than on peach fruits.

The eggs were laid on bark and on fruits. Most of the apricots were picked by the end of July so that observations after that time were made on peach fruits. Hatching started by 7 August. Larvae hatched from eggs on fruits made very small entry holes marked by brown frass on the surface; larvae hatched from eggs on bark started making overwintering chimneys in crotches of two-to four-year-old branches. They fed on the cambium to hollow out overwintering sites (hibernacula). Most of the larvae were in the first instar but a

few in the second instar were involved. These larvae were not seen to migrate from bark cells to fruit as reported in California by Bailey (1948).

Larvae in fruits developed normally although some made chimneys before starting to feed. They pupated from 5 to 12 September, and the emerged adults were seen from 14 to 28 September. These laid eggs mostly on bark but also on fruits which were left on the trees. Hatching occurred in the last week of September. Most of these newly-hatched larvae made hibernacula. Thus overwintering larvae are from eggs laid by third and second generation moths.

A few larvae were still feeding in fallen fruit at the end of September and had developed beyond the second instar. None could be found after mid-October, by which time night temperatures had dropped to about 4°C for a week (40°F).

DISCUSSION

Weldon (1914, cited from Duruz, 1923) concluded that the peach twig borer in California had a single, uneven generation per year, emerging over a long period. Duruz (1922, 1923), Bailey (1948) and Price & Summers (1961) observed three to four generations. King & Denman (1960) mentioned a fourth generation in Texas. The presence of hibernacula in August may have led earlier workers (Treherne, 1923; Venables, 1940; Proverbs, 1954) to assume that the August brood was the overwintering generation in the Okanagan Valley.

It appears that voltinism in this species is controlled not only by temperature, but also by food; larvae feeding on fruit in August developed and completed the third generation, whereas those feeding on bark built hibernacula.

The only parasite observed was a poly-embryonic chalcid, *Paralitomastix pyralidis* (Ashm.), which laid its eggs in the twig borer's eggs. Peach twig borer larvae from parasitized eggs died at maturity. At this time

the larvae were full of parasites which could be seen under a microscope through the translucent skin of the host. The adult chalcids emerge soon after the peach twig borer moths; oviposition in host and parasite is synchronized, and the parasite also has two or three generations per year. From 40 to 65 chalcid adults were seen to emerge from each host.

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A RECORD OF *Adranes taylori* WICKHAM (COLEOPTERA: PSELAPHIDAE)

A wind-thrown western red cedar of 18 inches diameter was found to have a 9-inch dead strip on one side. This was infested with termites and field ants, *Lasius sitkaensis* Pergande. The wood with the ants was kept in the laboratory and moistened regularly. After five months two small and unusual beetles emerged; these were *Adranes taylori* Wickham 1901, of subfamily Clavigerinae, family Pselaphidae. *Adranes* is a genus of obligate inquiline, restricted to the

nests chiefly of *Lasius* ants and known only from North America. Eight species are recorded from the Pacific Northwest (Hatch, M., 1962, Beetles of the Pacific Northwest, Vol. III). They are eyeless, with 3-segmented antennae, composed mostly of the very large 3rd segment, and have vestigial mouth parts. These are the only Clavigerinae in the University collection.

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ANOPLURA FROM BRITISH COLUMBIA AND SOME ADJACENT AREAS

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INTRODUCTION

In 1951 I reported (Spencer, 1952) that 25 named and several unidentified species of Anoplura had been obtained from the mammals of British Columbia. Since this time, I have received species from adjacent areas and have managed to recognise five additional species in British Columbia. It seems appropriate at this time to publish the list of species obtained, with their host data. Not many species occur that have not already been taken and recorded, although we may hope that some unexpected species still remain to be discovered.

MATERIALS AND METHODS

The records in this paper are based principally on specimens in the collections of the University of British Columbia but a few are from the Canadian National Collection [C.N.C.]; some were collected by many biologists for me over the years, and to these I am indebted. Besides the collections made in the field, I have systematically searched the dried skins in the Vertebrate Museum at the University for lice remaining attached. All the specimens of Anoplura were cleared and mounted on microscope slides, according to the method described by Spencer (1959). Determinations were made by myself, using the keys of Ferris (1951), and the list is arranged systematically, according to Ferris (1951). A host list is also appended, arranged according to Cowan & Guiguet (1960) and Walker *et al.* (1964). It will be apparent where extra collecting might prove rewarding.

I have a number of Mallophaga from the mammals of British Columbia, but it has not been possible to identify all the specimens. The list of these must therefore await further research.

Unless otherwise noted, all the specimens recorded here were taken in British Columbia.

SPECIES OF ANOPLURA

Family ECHINOPHTHIRIIDAE

Antarctophthirus microchir (Trouesart & Neumann)

ex. *Eumetopias jubata* (Schreber), Vancouver, 20.ix.1946 (G. J. Spencer); ex. *E. jubata*, Triangle Is., 15.vi.1953 (L. Margolis).

Originally recorded from *Phocarctos hookeri* in Auckland Is., and known also from *Zalophus californianus* and *E. jubata* from the coast of California.

A. trichechi (Bohemann)

ex. *Odobenus rosmarus rosmarus* (L.), N.W.T.: Ellesmere Is., Craig Harbour, 6.vi.1935 (H. Kearney).

ex. *Odobenus rosmarus divergens* (Ill.) ALASKA: Barrow, vii.1952 (F. H. Fay);

ex. *O. rosmarus divergens*, ALASKA: St. Lawrence Is., v.1954 (F. H. Fay).

Recorded from *O. rosmarus* previously from Greenland, Spitzbergen and adjacent regions.

In *A. trichechi*, the dorsal aspect of the head of the female is very different from that of the male; it has many large scales of two sizes, somewhat like the ventral aspect of the head of *A. microchir*.

Echinophthirius horridus (von Olfers)

ex. *Pusa hispida* (Schreber), N.W.T.: Baffin Is., Harbour, 14.i.1935 (Cpl. H. McBeth); ex. *P. hispida*, N.W.T.: Ellesmere Is., Craig Harbour, 20.iv.1935 (H. Kearney).

¹ This paper is based on specimens and notes left by the late Prof. Spencer. The plan of the paper was discussed with him and a first draft was seen by him prior to his death. I have attempted to include all the points that seem relevant.—G. G. E. Scudder.

ex. *Phoca vitulina richardii* (Gray), Skeena River, 16.vii.1946 (H. D. Fisher); ex. *P. v. richardii*, Vancouver Aquarium, in captivity, 26.iii.1963 (G. J. Spencer); ex. *P. vitulina*, Sointula, 20.vii.1966 (H. D. Fisher).

ex. *Phoca vitulina concolor* DeKay, N.B.: St. Andrews, vii.1951 (H. D. Fisher).

Described from *P. vitulina*. Recorded many times from this host on the coasts of Europe. Also reported from *P. groenlandica* and *Halichoerus gryphus* in Greenland, *P. hispida* from the Beaufort Sea, Alaska, *P. vitulina geronimensis* from Pacific Grove, California and *P. baikalensis* from Lake Baikal.

Proechinophthirius fluctus (Ferris)

ex. *Callorhinus ursinus cyanocephalus* (Walbaum), ALASKA, St. Paul Is., 15.vii.1946 (G. C. Carl).

Previously recorded from the Alaskan fur seal on St. Paul Is. and on other of the Pribilof Islands. The identity of the host of the type is doubtful.

Family HAEMATOPINIDAE

Haematopinus asini (Linnaeus)

ex. Horse, Vancouver, ii.1926 (M. A. Alan); ex. Horse, Kamloops, 10.iii.1938 (W. Godlonton); ex. Horse, Kamloops, 10.x.1943 (H. D. Fisher).

The type host is *Equus asinus*. Recorded also from domestic horses in various parts of the world and apparently occurring naturally on zebras.

H. eurysternus (Nitzsch)

ex. Bull, Kamloops, 10.iii.1938 (W. Godlonton); ex. Cattle, Douglas Lake, 20.ii.1944; ex. Cattle, Kamloops, 22.ii.1944 (G. J. Spencer).

Originally described from domestic cattle in Europe and known from these hosts from many parts of the world.

H. suis (Linnaeus)

ex. Hog, Quesnel, 15.vii.1949 (G. J. Spencer); ex. Hog, Vancouver, University of B.C., 4.xi.1954 (G. Cowan).

Recorded originally from domestic swine in Europe, and now known from this host from many parts of the world. It is reported from *Sus cristatus* in Tenasserim and India by

Ferris (1919-1935) and from Wild Hog in India by Spencer (unpublished).

Family HOPLOPLEURIDAE

Microphthirus uncinatus (Ferris)

ex. *Glaucomys sabrinus oregonensis* (Bachman), Vancouver, University of B.C. campus, 1.xi.1954, 15.xi.1954, 11.vii.1955, 12.viii.1955 (G. J. Spencer); ALTA., 1947.

Described from *G. sabrinus* in Yosemite National Park, California. The B.C. and Alberta records have been published before (Spencer, 1956) and at that time were apparently only the second captures of this louse.

Hoplopleura acanthopus (Burmeister)

ex. *Ochotona princeps fenisei* Osgood, Fraser River, 24 miles W. of Williams Lake, 7.xi.1946 (J. Hatter)—ex. Museum skin.

ex. *Thomomys talpoides fuscus* Merriam, Anarchist Mt., 29.v.1941 (I. McT. Cowan)—ex. Museum skin.

ex. *Synaptomys borealis chapmani* Allen, ALTA.: Banff, 6.ix.1930 (I. McT. Cowan); ALTA.: Jasper Park, Elysium Pass, 26.vi.1946 (I. McT. Cowan)—ex. Museum skin; Wells Gray Park, Murtle Lake, 24-26.vii.1950 (P. Martin).

ex. *Lemmus trimucronatus trimucronatus* (Richardson), N.W.T.: Baffin Is. Clyde, 10.vi.1958 (J. E. H. Martin) [C.N.C.].

ex. *Neotoma cinerea occidentalis* (Baird), Chilcotin River Valley, 29.v.1929 (G. J. S.).

ex. *Sorex cinereus cinereus* Kerr. ONT.: Algoma District, Pancake Bay, 4.ix.1935 (C. H. D. Clarke) [C.N.C.].

ex. *Clethrionomys gapperi saturatus* (Rhoads), Princeton, 23.viii.1965 (W. Sheppe).

ex. *Rattus norvegicus* (Berkenhout), Vancouver, 4.ix.1940 (J. Poole).

ex. *Microtus pennsylvanicus drummondii* (Audubon & Bachman), Nicola Range, Minnie Lake, 17.vi.1932 (G. J. Spencer); Grindrod, 12.iii.1948, 24.iii.1948, 1.v.1948 (J. Wynne).

ex. *Microtus townsendii* (Bachman), Vancouver, 18.ix.1934 (R.A.C., G.J.S.); Vancouver, 13.iv.1955 (G. Rolandson); Vancouver, University of B.C., 14.iii.1959 (J. Lanko).

ex. *Microtus montanus canescens* Bailey, Kamloops, Lac du Bois, 1.vii.1936 (G. J. Spencer).

ex. *Microtus longicaudus mordax* (Merriam), WASH., American & Bumping R., 20.vii.1957 (W. Sheppe); WASH.: River Bend Camp, 29.vi.1957 (W. Sheppe); WASH.: Crystal Springs Camp, 7.vii.1957 (W. Sheppe); Princeton, 31.vii.1965 (W. Sheppe); 4 miles S.W. of Princeton, 23.viii.1965 (W. Sheppe).

ex. *Microtus longicaudus vellerosus* Allen, Mount Robson, Berg Lake, 26.vii.1944.

ex. *Microtus oregoni serpens* Merriam, Vancouver, 15.iii.1955 (G. J. Spencer).

Originally described from *Microtus arvalis*, from Europe. Recorded also from *M. agrestis* and *M. nivalis* in Europe; *M. californicus*, *M. intermedius* and *M. ochrogaster* in the U.S.A.; *Lemmus alaskensis* in Alaska; *Synaptomys borealis* in Canada; *Pitymys pinetorum* in the eastern U.S.A. and on *Mus* in Europe. The occurrences reported here on *Ochotona*, *Clethrionomys*, *Rattus* and several species of *Microtus* therefore appear to be new host records.

H. arboricola (Kellogg & Ferris)

ex. *Eutamias amoenus affinis* (Allen), Savona, Deadman's Creek, 14.viii.1934 (D. Cameron & G. J. Spencer); Kamloops, Lac du Bois, 30.v.1934 (D. Cameron & G. J. Spencer); 17 miles from Kamloops, on Nicola road, 13.vi.1934 (D. Cameron & G. J. Spencer); Aspen Grove, 17.vii.1932, 28.viii.1934, 18.viii.1935 (G. J. Spencer); Rayleigh, 18.viii.1935 (G. J. Spencer); Tranquille range, Davis ranch, 19.vii.1934 (D. Cameron & G. J. Spencer).

ex. *Eutamias amoenus luteiventris* (Allen). Kinbasket Lake, 4.viii.1943 (G. P. Holland & G. J. Spencer).

The type host is *Eutamias townsendii* (= *Neotamias hindsi*) from California. According to Kellogg & Ferris (1915), Ferris (1919-1935) and Ferris (1951) the British Columbia material listed above, runs to *arboricola* and not *H. erratica* (Osborn), but other more atypical specimens have

been taken from *Eutamias* in the Province.

H. hesperomydis (Osborn)

ex. *Peromyscus sitkensis prevostensis* Osgood, Queen Charlotte Islands, Frederick Is., 25.vi.1946, 11.vii.1947 (C. Guiguet) — ex. Museum skin; Queen Charlotte Islands, Knight Is., 11.vii.1947 (C. Guiguet)—ex. Museum skin; Queen Charlotte Islands, Hippa Is., 25.vi - 11.vii.1947 (C. Guiguet); Queen Charlotte Islands, Lina Is., 27.vi.1960 (P. Joslin).

ex. *Peromyscus maniculatus austerus* (Baird), Vancouver, West Point Grey, 17.xi.1946 (J.D.Y., G.J.S.); Cultus Lake, 27.iii.1948 (J. Yarwood); Vancouver, 28.i.1948, 29.iii.1951, 2.ii.1959 (G. J. Spencer); Vancouver, Point Grey, 19.ii.1959 (J. Macdonald); Haney, Loon Lake, 29.viii.1957 (W. Sheppe).

ex. *Peromyscus maniculatus oreas* Bangs, Alta Lake, 28.viii.1941 (I. McT. Cowan); Vancouver, 14.i.1954 (G. J. Spencer); Princeton, 31.vii.1965 (W. Sheppe).

ex. *Peromyscus maniculatus artemisiae* (Rhoads), Kamloops, 9.vi.1929, 21.vii.1934 (G. J. Spencer); Aspen Grove, 12.vi.1932 (G. J. Spencer); Kamloops, Lac du Bois, 27.viii.1939 (G. J. Spencer); Armstrong, 4.ii.1941 (I. McT. Cowan); Princeton, 12.viii.1957 (W. Sheppe).

ex. *Peromyscus* sp., Vancouver, University of B.C.: 31.v.1940 (G. J. Spencer); Mahood Lake, 9.vii.1950 (P. W. Martin); Mount Seymour, 22.vii.1965 (W. Sheppe).

Described from *Peromyscus leucopus* in Iowa. Recorded from *P. boylii* and *P. maniculatus* in California; *Onychomys torridus* in California; *O. leucogaster* in Colorado; *Oryzomys fulvescens* in Mexico; *Oryzomys chaparensis* in Bolivia; *Eligmodontia collisae* in Argentina; *Mus musculus* in the U.S.A. and Turkestan; *Mus gansus* and *M. wagneri* in China. The occurrences reported here on *P. sitkensis* thus appear to be a new host record.

H. oenomydis Ferris

ex. *Rattus norvegicus* (Berkenhout), Vancouver, 4.ix.1940 (J. Poole).

Originally described from *Oenomys hypoxanthus* in East Africa. Recorded from *Dasymys incomtus* and *Grammomys surdaster* in East Africa; *Rattus exulans* and *R. mearnsi* in the Philippines; *Rattus exulans* in Hawaii and the Marquesas, and on *R. norvegicus* in the south-eastern U.S.A.

H. sciuricola Ferris

ex. *Tamiasciurus hudsonicus streator* (Allen), Nicola, Coyote Valley, 26.vi.1933 (T. K. M., D. C., G. J. S.); Aspen Grove, 21.viii.1934 (D. Cameron); Grindrod, 6.xii.1946 (J. Wynne).

ex. *T. hudsonicus*, Vancouver, 2.iv.1949 (G. J. Spencer); Grindrod, 19.ii.1947 (J. Wynne).

ex. *Tamiasciurus douglasi mollipilosus* (Audubon & Bachman), Vancouver, 4.ii.1952 (G. J. Spencer); Gambier Is., 21.ii.1943 (I. McT. Cowan).

Originally described from *Sciurus carolinensis* from Mississippi. Reported from *T. hudsonicus* in Alaska, *T. douglasi* in California, *S. ignitus* in Peru, *S. nasaeus* in Venezuela and *S. variabilis* in Colombia.

H. trispinosa Kellogg & Ferris

ex. *Glaucomys sabrinus columbiensis* Howell, Princeton, 6.x.1957 (W. Sheppe).

ex. *Glaucomys sabrinus oregonensis* Bachman, Vancouver, University of B.C. campus, 26.i.1944, 12.viii.1955, 11.vii.1955, 15.xi.1954 (G. J. Spencer); ALTA.: 1947 (Spencer, 1956).

Originally described from *G. sabrinus* from Oregon. Recorded on this species also in California, B.C., and Alberta (Spencer, 1956) and on *G. volans* in Maryland.

Pedecinus eurygaster (Burmeister)

ex. Rhesus monkey, Vancouver, University of B.C., in captivity 1934 (G. J. Spencer).

Recorded from *Macaca*, *Cercopithecus*, *Pithecus* and *Rhinopithecus*, both wild and captive.

P. obtusus (Rudow)

ex. Rhesus monkey, Vancouver, University of B.C., in captivity, 5.iii.1934 (G. J. Spencer); Vancouver, in captivity, 10.v.1953 (G. J. Spencer).

Originally from *Semnopithecus maurus*, but may occur on almost any Cercopithecoid monkey, either wild or captive. It is the species most likely to be found on captive monkeys.

Fahrenholzia pinnata Kellogg & Ferris
ex. *Perognathus parvus lordi* (Gray), Osoyoos, 21.v.1941 (I. McT. Cowan)—ex. Museum skin; 10 miles S. of Oliver, 7.vii.1963 (W. B. Preston)—ex. Museum skin.

Apparently this species also from *Perognathus parvus laingi* Anderson, Okanagan Landing, 11.viii.1949 (I. McT. Cowan)—ex. Museum skin.

Originally described from *Dipodomys californicus* in California, and noted from *D. merriami* and *Perognathus* sp. in the same State, *D. ornatus* and *D. phillipsii* in Mexico, and *Perognathus parvus* in Nevada.

Haemodipsus ventricosus (Denny)

ex. Laboratory rabbit, Vancouver, University of B.C., 27.i.1942, 14.x.1934 (G. J. Spencer); ex. rabbit, Vancouver, 24.x.1931 (G. J. Spencer).

Described from the European rabbit, *Oryctolagus cuniculus* in England. Recorded from this host and from its domestic descendants in many parts of the world.

Neohaematopinus inornatus (Kellogg & Ferris)

ex. *Neotoma cinerea occidentalis* Baird, Chilcotin R. Valley, 29.v.1929 (G. J. Spencer); Nicola, 24.viii.1933 (G. J. Spencer); Vavenby, 25.x.1933 (G. J. Spencer); Cariboo, Dempsey Lake, 12.viii.1934 (D. Cameron & G. J. Spencer); Kamloops, Lac du Bois, 7.ix.1938 (G. J. Spencer).

ex. *Neotoma cinerea* (Ord), WASH.: American & Bumping R., 22.vii.1957 (W. Sheppe).

Described from *Neotoma cinerea* in California, and known from the same host also in Colorado.

N. laeviusculus (Grube)

ex. *Spermophilus columbianus columbianus* (Ord), Birch Is., 6000 feet, 12.viii.1931 (G. J. Spencer); 30 miles from Vernon, on Vernon-Kamloops road, 27.v.1934 (D. C. & G. J. Spencer);

Lower Arrow Lakes, Syringa Creek, 30.vi.1934, 6.vii.1934 (D. Cameron); Grand Forks, 15.v.1939 (J. B. Poole); Bridesville plateau, 25-30.vi.1940 (J. Poole); Windermere - Golden, 20.vii.1940 (J. Poole); Yoho Park, 2.viii.1940 (J. Poole); Mt. Tod, 27.vi.1943 (G. J. Spencer); Kennedy Lake, 3.v.1956 (W. Sheppe).

ex. *Spermophilus undulatus parryi* (Richardson), N.W.T.: Thelon R., Lookout Point, 7.viii.1963 (J. F. Bendell)—ex. Museum skin;

ex. *S. undulatus*, N.W.T.: Fort Smith, 25.viii.1965 (E. Kuyt).

Described from *Citellus eversmani* in Siberia. Known from many other species of *Spermophilus* in North America, from Point Barrow in Alaska, south to Mexico. Recorded from *Cynomys leucurus* in Colorado. The use of *Spermophilus* rather than *Citellus* follows Hall and Kelson (1959).

N. marmotae Ferris

ex. *Marmota flaviventris avara* (Bangs), Nicola, 14.v.1931 (R. T. Turner); Kamloops, 8.vi.1934 (D. Cameron); Agassiz, 15.vi.1934 (W. Riley); Rayleigh, 2.viii.1934 (D. Cameron); Tranquille, 21.vii.1934 (D. Cameron); Tranquille range, Davis ranch, 3.vi.1934 (D. Cameron, G. J. Spencer); Kamloops, Lac du Bois range, 2.vi.1935 (G. J. Spencer); Kamloops, Strawberry Heights, 23.ii.1936 (L. C. Curtis, G. J. Spencer); Kamloops, 4.viii.1935 (I. Ward, G. J. Spencer); Upper Hat Creek, 30.vi.1935 (I. Ward); Tranquille, 17.xi.1937 (G. P. Holland, G. J. Spencer); Keremeos, 30.iii.1959 (G. Gibson).

ex. *Marmota monax petrensis* Howell, Oliver (Fairview), 17.iv.1934 (E. R. Buckell, G. J. Spencer); Kootenays, Alder Creek, 12.vi.1932; Kootenays, Sirdar, 20.viii.1949 (I. McT. Cowan).

ex. *Marmota caligata okanagana* (King), Birch Is., 6000 feet, 12.viii.1931 (G. J. Spencer); Dunn Peak, 9.viii.1937, 8000 feet (G. P. Holland, G. J. Spencer).

ex. *Marmota caligata nivaria* Howell, MONTANA: Whitefish Range, 19.vii.1965 (C. Jonkel).

ex. *Cynomys ludovicianus ludovician-*

us (Ord), SASK.: 13 miles S.E. of Val Marie, 6.vii.1942 (G. P. Holland).

ex. *Mustela frenata nevadensis* Hall, Nicola range, Dry Farm, 1.ix.1932 (G. J. Spencer): apparently this species.

Described originally from *Marmota flaviventris* in California and known from *Marmota* in Montana, Idaho and Colorado.

N. sciurinus Mjöberg

ex. *Tamiasciurus hudsonicus streator* (Allen), Aspen Grove, 21.viii.1934 (D. Cameron); Kamloops, 4.viii.1935 (G. J. Spencer); Nicola range, 2.xi.1932 (G. J. Spencer); Grindrod, 28.xii.1947 (J. Wynne).

ex. *Tamiasciurus hudsonicus columbiensis* Howell, Chilcotin, Riske Creek, 29.vi.1930 (G. J. Spencer).

ex. *Tamiasciurus hudsonicus lanuginosus* (Bachman), Courtenay-Comox, Miracle Beach, 1.viii.1960 (W. J. Merillees).

ex. *Sciurus carolinensis pennsylvanicus* Ord. Vancouver, Stanley Park.*

Described from *Sciurus niger rufiventer* in Iowa. Recorded from many species of *Sciurus* from North, Central and South America and the Malayan region.

N. sciuropteri (Osborn)

ex. *Glaucomys sabrinus alpinus* (Richardson), Hazelton, Terano Lake, 11.v.1938 (J. F., G. J. Spencer).

ex. *Glaucomys sabrinus columbiensis* Howell, near Kelowna, Canyon Creek, Kettle Valley, Res. 2, xii.13 (Gillard); Kamloops, 10.ii.1934 (G. J. Spencer); Princeton, 6.x.1957 (W. Sheppe).

ex. *Glaucomys sabrinus oregonensis* (Bachman), Vancouver, West Point Grey, 26.i.1944 (G. J. Spencer); Vancouver, University of B.C. campus, 1.xi.1944, 15.xi.1954, 11.vii.1955, 12.viii.1955 (G. J. Spencer).

ex. *Glaucomys sabrinus*, ALTA., 1947 (Spencer, 1956).

ex. *Eutamias amoenus affinis* (Allen), Aspen Grove, 24.vii.32 (G. J. Spencer).

Described from *Glaucomys volans* in Iowa and known also from *G. sabrinus* in California. Previously re-

* Anoplura specimens not seen by G. G. E. S.

corded from *G. sabrinus* in B.C. and Alberta by Spencer (1956).

Polyplax auricularis Kellogg & Ferris
ex. *Peromyscus maniculatus borealis* Mearns, ALTA.: Devona, 18.iv.1943 (I. McT. Cowan).

ex. *Peromyscus maniculatus oreas* Bangs, WASH.: Crystal Springs Camp, 7.vii.1957 (W. Sheppe).

The type of this species was taken from *Peromyscus maniculatus* in California. It is recorded from *P. sitchensis* in Alaska, *Onychomys torridus* in California, *O. leucogaster* in Colorado and Kansas. In Mexico it occurs on *Reithrodontomys mexicanus* and *Neotomodon alstoni*.

P. spinulosa (Burmeister)

ex. *Microtus oregoni serpens* Merriam, Vancouver, 15.iii.1955 (G. J. Spencer).

ex. *Rattus norvegicus* (Berkenhout), Tofino, 20.vi.1926 (G. J. Spencer); Burrard Inlet, 15.ix.1938 (J. Poole); Vancouver, 15.ix.1938, 4.ix.1940 (J. B. Poole); Vancouver, University of B.C., 6.xi.1938 (G. J. Spencer); Vancouver, 9.xii.1939, 28.v.1958, 5.iv.1959 (G. J. Spencer), 6.xii.1957 (H. B. Mitchell).
ex. *Rattus rattus rattus* (Linnaeus), Vancouver, 15.x.1946 (J. Y., G. J. Spencer), 29.ix.1955 (G. J. Spencer), 21.ii.1955.

ex. *Rattus*, Vancouver, 9.iii.1935 (K. Jacob), 5.x.1939 (G. J. Spencer).
ex. White Rat, Vancouver, University of B.C., in captivity, 5.x.1939 (G. J. Spencer).

Described from *Rattus norvegicus* in Europe. Known from *R. rattus* and *R. norvegicus* in many parts of the world. Recorded also from other *Rattus* species in the Philippines and Malaya, *Bandicota* in Burma and *Thallomys* in South Africa.

Family LINOGNATHIDAE

Linognathus pedalis (Osborn)

ex. Domestic sheep, Vancouver, University of B.C., v.1925 (G. J. Spencer).

First described from domestic sheep in the U.S.A. and now known from South America, New Zealand, Australia and South Africa.

L. setosus (von Olfers)

ex. Dog, Vancouver, i.1931, 5.v.1943, ix.1945, 26.xi.1955 (G. J. Spencer), 3.i.1962 (G. Armstrong); Kamloops, 5.vii.1936 (G. J. Spencer); Victoria xii.1942 (W. Downes).

Originally described from domestic dog in Europe: now known throughout the world. Also recorded from *Alopex lagopus* in Canada and Alaska, fox in Manchuria, *Canis lupus* in Croatia, coyote in the U.S.A., and the ferret and rabbit.

L. stenopsis (Burmeister)

ex. Angora Goat, ALTA.: Suffield, 27.xi.1945 (student).

Described originally from the domestic goat in Europe. Known from this host in many parts of the world. Also recorded from *Capra ibex* and *Rupicapra rupicapra*.

L. vituli (Linnaeus)

ex. Cattle, Cariboo, Canim Lake, 14.iii.1944; Milner, 26.xii.1944 (G. J. Spencer).

Described from domestic cattle in Europe. Since reported from this host in many parts of the world.

Solenopotes capillatus Enderlein

ex. Cattle, Kamloops, 20.vii.1949 (G. B. Rich).

First recorded from domestic cattle in Germany. Now known from cattle in Europe and North America.

S. ferrisi (Fahrenholz)

ex. *Odocoileus hemionus columbianus* (Richardson), Comox, Vancouver Is., 9.xi.1930 (G. J. Spencer); Hardy Is., 3.iv.1943 (G. J. Spencer); Pender Is., 4.i.1945 (G. J. Spencer).

ex. *Cervus canadensis* (Erxleben), ALTA.: Jasper Park, 20.xii.1944 (I. McT. Cowan).

ex. *Tamiasciurus hudsonicus columbiensis* Howell, Clinton, (J. & W. Hooke): adventitive.

Originally described from *Odocoileus columbianus* in California.

Family PEDICULIDAE

Pediculus humanus capitis DeGeer.

ex. Man, Salmon Arm, 1928 (H. Leech); ex. North American Indian, Alexis Creek, iii.1939 (Dr. Hallows).

P. humanus corporis DeGeer.

ex. Man, Vancouver, 7.xii.1944 (G. J. Spencer), 16.iv.1950 (E. Fridell).

ex. Man, Essondale, 25.vii.1936 (W.T.); Vancouver, ix.1940 (W. McK. McCallum).

Phthirus pubis (Linnaeus)

Host list of Anoplura recorded in this paper:

Order INSECTIVORA

Family SORICIDAE

*Sorex cinereus cinereus**Hoplopleura acanthopus*

Order PRIMATES

Family CERCOPITHECIDAE

Macaca mulatta (Rhesus Monkey)*Pedicinus eurygaster**P. obtusus*

Family HOMINIDAE

Homo sapiens (Man)*Pediculus humanus**Phthirus pubis*

Order LAGOMORPHA

Family OCHOTONIDAE

*Ochotona princeps fenisex**Hoplopleura acanthopus*

Family LEPORIDAE

Oryctolagus cuniculus (Domestic rabbit)*Haemodipsus ventricosus*

Order RODENTIA

Family SCIURIDAE

*Marmota monax petrensis**Neohaematopinus marmotae**M. flaviventris avara**N. marmotae**M. caligata nivaria**N. marmotae**M. caligata okanagana**N. marmotae**Cynomys ludovicianus ludovicianus**N. marmotae**Spermophilus columbianus columbianus**N. laeviusculus**S. undulatus**N. laeviusculus**Eutamias amoenus affinis**Hoplopleura arboricola**E. amoenus luteiventris**H. arboricola**E. amoenus septentrionalis**H. arboricola**Sciurus carolinensis pennsylvanicus**Neohaematopinus sciurinus**Tamiasciurus hudsonicus columbiensis**N. sciurinus**T. hudsonicus lanuginosus**N. sciurinus**T. hudsonicus streatorum**N. sciurinus**Hoplopleura sciuricola**T. douglasi mollipilosus**H. sciuricola**Glaucomys sabrinus alpinus**N. sciuropteri**G. sabrinus columbiensis**H. trispinosa**N. sciuropteri**G. sabrinus oregonensis**H. trispinosa**N. sciuropteri**Microphthirus uncinatus*

Family GEOMYIDAE

*Thomomys talpoides fuscus**H. acanthopus*

Family HETEROMYIDAE

*Perognathus parvus lordi**Fahrenholzia pinnata*

Family CRICETIDAE

*Peromyscus maniculatus artemisiae**H. hesperomydis**P. maniculatus austerus**H. hesperomydis**P. maniculatus borealis**Polyplax auricularis**P. maniculatus oreas**H. hesperomydis**P. sitkensis prevostensis**H. hesperomydis**Neotoma cinerea occidentalis**N. inornatus**Synaptomys borealis chapmani**H. acanthopus**Lemmus trimucronatus trimucronatus*

- H. acanthopus*
Clethrionomys gapperi saturatus
H. acanthopus
Microtus oregoni serpens
H. acanthopus
Polyplax spinulosa
M. pennsylvanicus drummondi
H. acanthopus
M. montanus canescens
H. acanthopus
M. townsendi
H. acanthopus
M. longicaudus mordax
H. acanthopus
M. longicaudus vellerosus
H. acanthopus
- Family MURIDAE
Rattus rattus rattus
P. spinulosa
Rattus norvegicus
H. acanthopus
H. oenomydis
P. spinulosa
- Order CARNIVORA
 Family CANIDAE
Canis (Domestic dog)
Linognathus setosus
- Family MUSTELIDAE
Mustela frenata nevadensis
N. marmotae
- Order PINNIPEDIA
 Family OTARIIDAE
Callorhinus ursinus cyanocephalus
Proechinophthirius fluctus
Eumetopias jubata
Antarctophthirus microchir

Family ODOBENIDAE

- Odobenus rosmarus divergens*
Antarctophthirus trichechi
O. rosmarus rosmarus
A. trichechi

Family PHOCIDAE

- Phoca vitulina concolor*
Echinophthirius horridus
P. vitulina richardi
E. horridus
Pusa hispida
E. horridus

Order PERISSODACTYLA

Family EQUIDAE

- Equus caballus* (domestic horse)
Haematopinus usini

Order ARTIODACTYLA

Family SUIDAE

- Sus scropha* (Domestic swine)
H. suis

Family CERVIDAE

- Cervus canadensis*
Solenopotes ferrisi
Odocoileus hemionus columbianus
S. ferrisi

Family BOVIDAE

- Bos taurus* (Domestic cattle)
Haematopinus eurysternus
Linognathus vituli
Solenopotes capillatus
Capra (Domestic goat)
Linognathus stenopsis
Ovis aries (Domestic sheep)
L. pedalis

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OVERWINTERING OF CAGED *Rhyacionia buoliana* (SCHIFFERMULLER) AT VERNON, B.C., IN 1965-66

D. A. Ross¹

INTRODUCTION

The European pine shoot moth, *Rhyacionia buoliana* (Schifferrmuller), is established in exotic pines in southern coastal British Columbia and since 1961 has occurred in small numbers on imported exotic pines in the Okanagan-Kamloops region. Only one specimen has been taken from a native tree, a mature ponderosa pine, *Pinus ponderosa* Lawson and Son, on the Department of Agriculture of Canada Experimental Station at Summerland. As it is believed that the shoot moth may become a pest in the interior forests of the Pacific Northwest, surveys have been intensified and in some regions quarantines and control measures have been implemented. An attempt has also been made to determine the ability of the European pine shoot moth to overwinter successfully in the North Okanagan Valley, at Vernon, in the range of lodgepole and ponderosa pines.

During the summer of 1963 one pair of moths was caged with a small ponderosa pine; eggs were laid and at least two hatched. The larvae bored into the base of the needles, but none were found in May 1964. The ability of the insect to overwinter in British Columbia was further investigated in 1965 and is reported here.

METHODS

On 26 May 1965, several hundred tips of mugho pine infested with European pine shoot moth were collected on the campus of the University of B.C. in Vancouver. Adults from the collection, reared in the insectary at Vernon, were introduced to caged

young ponderosa pine trees, and to sleeve cages on a mature ponderosa pine tree. Arthropods in the cages were destroyed before the moths were introduced, to eliminate predators of the shoot moth and to avoid confusion with damage caused by other insects. The cages were removed in September to permit complete exposure of the twigs to winter conditions and replaced early in April before larval activity began.

Large cage. Seven ponderosa pine trees 4 to 5 feet in height were transplanted at Vernon in April 1965, and late in May the trees were covered with a portable cage 12' x 12' x 6'. The cage was a wooden frame covered with factory cotton with several screened panels to improve ventilation. A pitched canvas roof over the cage shed heavy rainfall and provided shade. Shortly before the eggs hatched, the screens were covered with transparent plastic to prevent escape of the larvae.

Pairs of moths, the male 1-2 days older than the female, were maintained overnight on June 10 in fifty separate small cages that were furnished with water and a pine twig. The next afternoon the females were introduced to the large cage; June 11-19, twenty males were released in the cage and on July 9, three females and two males.

Sleeve cages. The sleeve cages 6 feet long and 2½ feet in diameter, were made of a cylindrical wire frame covered with nylon screen. These cages were slipped over individual branches of a mature ponderosa pine with two pairs of moths in each.

RESULTS

Large cage. By 22 July numerous European pine shoot moth larvae had

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become established, evidence being holes in the needle bases and frass and pitch masses on the twig ends. One larva, believed to be *Rhyacionia*, was observed on a silken thread the same day. Ants were numerous within the large cage and may have destroyed some of the shoot moth eggs and larvae.

In September 1965, six of the seven trees tested had evidence of larval feeding. The number of damaged twigs per tree was: 16, 6, 6, 3, 3 and 2. Two trees with nine infested twigs, and the larvae, died. From the 27 infested twigs on the other four trees, nine pupae were recovered, all from twigs above the snow line.

Sleeve cages. No larvae established themselves in the twigs.

DISCUSSION AND CONCLUSIONS

The lowest temperatures in the Vernon area during the overwintering period in 1965-66 occurred near the end of December. On December 29 the temperature was -2°F and on January 5 it was -4°F . Green (1962) showed that in Ontario a temperature of -4°F could kill 45% of the larvae in November but only 7% in mid-February. He demonstrated that temperatures below -22°F completely destroyed larval populations.

The successful overwintering of 9 larvae on twigs above snow level indicates that *Rhyacionia buoliana* can survive winter temperatures in the North Okanagan Valley as low as -4°F .

Reference

- Green, G. W. 1962. Low winter temperatures and the European pine shoot moth, *Rhyacionia buoliana* (Schiff.) in Ontario. *Can. Ent.* 94: 314-336.

EDITORIAL NOTES

In its sixty-year life this society has never been so hard-hit by deaths as it was in 1966. Three of our most revered members, two of them Honorary Members, have now gone. Even though they died full of years and honour we feel the loss, and the gaps they leave will be hard to fill.

Several inquiries have been received concerning a suitable memorial for the late Prof. Spencer. The Alumni Annual Giving Society of the University of British Columbia is sponsoring an annual lectureship, to be known as the Spencer Memorial Lectures. The intention is to invite world figures in entomology to speak at the University at some convenient time during the academic year. A committee has been struck under the chairmanship of Dr. G. G. E. Scudder.

In the near future the A.A.G. will ask for donations from former students and friends of Prof. Spencer.

At the annual meeting on 18 March, 1966, in Vernon, it was decided to change the name of this publication from *Proceedings* to *Journal*. It has long since ceased to be a true proceedings in that presidential addresses and the proceedings and transactions at meetings were not reported. Since contributions to the publication are fully reviewed it is fitting that this policy be recognized by the change of name.

The next issue of the *Journal* will go to press within four months from the spring meeting, in accordance with a motion passed at the meeting of 18 March, 1966. Contributors are asked to submit their manuscripts by or before that time.

THE IMMATURE STAGES OF *Cenocorixa bifida* (HUNG.) AND *C. expleta* (UHLER) (HEMIPTERA: CORIXIDAE)

G. G. E. SCUDDER

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of British Columbia, Vancouver

INTRODUCTION

In a study of the ecology and physiology of Corixidae living in a series of soda lakes in central British Columbia, it was essential to identify the larval instars of two species of *Cenocorixa*, which often occur sympatrically. This was necessary in order to work out the details of the life cycle and be able to identify with certainty, insects used in experiments. This paper describes the immature stages of these two species, *C. bifida* (Hungerford) and *C. expleta* (Uhler). Both species have been previously recorded from British Columbia by Lansbury (1960).

MATERIALS and METHODS

The immature stages were obtained in two ways. Firstly, regular samples of larvae were obtained in field collections. Secondly, eggs were obtained from adult insects and reared. Gravid females were taken from White Lake and Long Lake in the Cariboo region of central British Columbia in April 1966 and were transported to the laboratory in one gallon Thermos jugs, half filled with water. Insects were then placed in natural lake water in plexiglass dishes with vegetation and nylon netting for them to cling to. At 20°C and under natural light conditions, females laid eggs within 48 hours. These eggs were separated from the insects at frequent intervals: this was to prevent them being used as food by the females. Batches of eggs were placed in finger bowls with the appropriate water and kept at 20°C and under natural light conditions. Larvae on emergence were fed every other day on young brine shrimp (*Artemia salina* (L.)) which were hatched sepa-

rately in the corresponding lake water. In this way, *C. bifida* was reared to the adult instar and *C. expleta* through the first three larval instars.

All drawings have been made with a squared reticule eye-piece or Camera Lucida, using both compound and stereo-zoom microscopes. The spines on the hind femora of larvae were usually only clearly visible when legs were mounted in polyvinyl lactophenol or other similar mountant and viewed at magnifications over 150x.

The terminology and characters utilized in the larval descriptions follow Cobben & Pillot (1960). However, I have interpreted the surfaces of the legs differently. The surface of the hind leg seen in dorsal view is morphologically the posterior surface and is so interpreted. Likewise the surface seen ventrally is the anterior face, the morphological ventral surface being the one towards the insect body when it is at rest or swimming.

EGGS

To date it has not been possible to distinguish between the eggs of the two species. Both have top-shaped eggs, with a very short stalked disc, smooth chorion, height 0.78 mm. and width 0.57 mm. The egg of *C. bifida* is shown in Fig. 1, just before hatching. At eclosion, the apex of the chorion splits into 6-8 wedges.

In the laboratory, *C. expleta* usually laid eggs on the walls of the container, while *C. bifida* laid most eggs on the vegetation or plastic screen. In the field, *C. expleta* has been found to lay eggs on rock boulders and *bifida* on vegetation, often in the leaf sheath of somewhat decayed submerged grasses. However, this may not be the only oviposition habit of the two species.

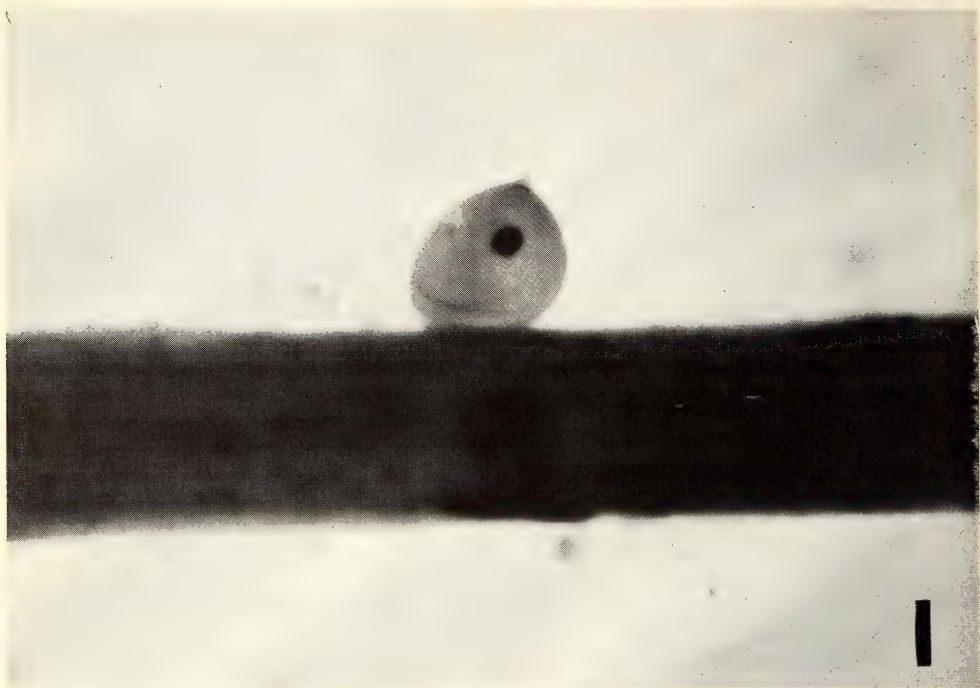


Fig. 1—Photograph of the egg of *Cenocorixa bifida* just before hatching.

LARVAE

(1) General description of *Cenocorixa* larvae:

Rostrum with transverse furrows; frons not greatly hirsute; eyes red. Pala spatulate; middle legs with tarsus longer than tibia; hind tibia posteriorly with a row of 7 moveable spines. Metasternal xiphus short and equilateral. Abdomen laterally moderately convex; dorsal abdominal scent gland and opening on tergum III obsolete; scent glands and ostioles on terga IV and V distinct, the ostioles paired; abdomen without distinct colour pattern.

Latter instars with a dense hair covering on mesonotum, but without this reaching anterior margin (Fig. 6); hairs on median area of anterior mesonotum short; mesonotum with hind margin covered with long hairs only in middle, the lateral areas bare and relatively broad. Metanotum without long hair covering, but with sparse short and slender setae; inner margin of wing pads with line of

dense long hairs. Most instars with a distinct comb on hind tibia distally on posterior side.

(2) Separation of species

The following couplet will separate the larvae of *C. bifida* from those of *C. expleta*:

Pala with apical lower palmar bristle situated on a distinct prominence; terminal claw relatively slender, hardly thicker than preapical lower palmar bristle (Fig. 9) *C. bifida*

Pala with apical lower palmar bristle situated on an indistinct prominence; terminal claw distinctly thicker than preapical lower palmar bristle (Fig. 10) *C. expleta*

With the above characters, it is possible to separate the species in each larval instar and in the adult.

(3) Key to larval instars

The following key will separate the instars in both *C. bifida* and *C. expleta*.

1. Meso and metanotum with covering of long hairs on at least part; hind femur with tuft of long hairs antero-ventrally and with 4 short bristles dorsally; hind tibia with row of dense swimming hairs posteriorly 3.
 - Meso and metanotum without long dense hair covering; hind femur without tuft of long hairs antero-ventrally, but with 5 long outstanding setae dorsally; hind tibia without row of dense swimming hairs posteriorly, only a few scattered hairs present. 2.
 2. Postero-lateral corners of mesonotum curved distinctly caudad; hind tibial comb with 2 spines; hind tibia with 5-7 long hairs posteriorly. second instar
 - Postero-lateral corners of mesonotum not curved distinctly caudad; hind tibial comb of a single spine; hind tibia with 2-3 long hairs posteriorly. . . first instar
 3. Hind tibial comb with 4 spines; long hair covering on mid-line of mesonotum not reaching posterior margin; fore wing buds overlapping less than half of the hind wing buds; fore wing buds not reaching base of abdomen. third instar
 - Hind tibial comb with 6 or 8 spines; long hair covering on mid-line of mesonotum reaching posterior margin; fore wing buds overlapping more than half of hind wing buds; fore wing buds reaching base of abdomen. . . 4.
 4. Hind tibial comb with 6 spines; wing buds not completely overlapping but reaching second abdominal segment; fore wing buds reaching but not surpassing base of abdomen. . . . fourth instar
 - Hind tibial comb with 8 spines; wing buds completely overlapping and reaching third abdominal segment; fore wing buds surpassing base of abdomen. . . fifth instar
 - (4) Description of larvae of *C. bifida*
- Table I summarizes the most important characters of the larvae of

C. bifida. The descriptions below omit most of the characters of instars found in the key. In the counts of spines on the femur, all totals cited omit the two apical spines found at the apex on anterior and posterior surfaces.

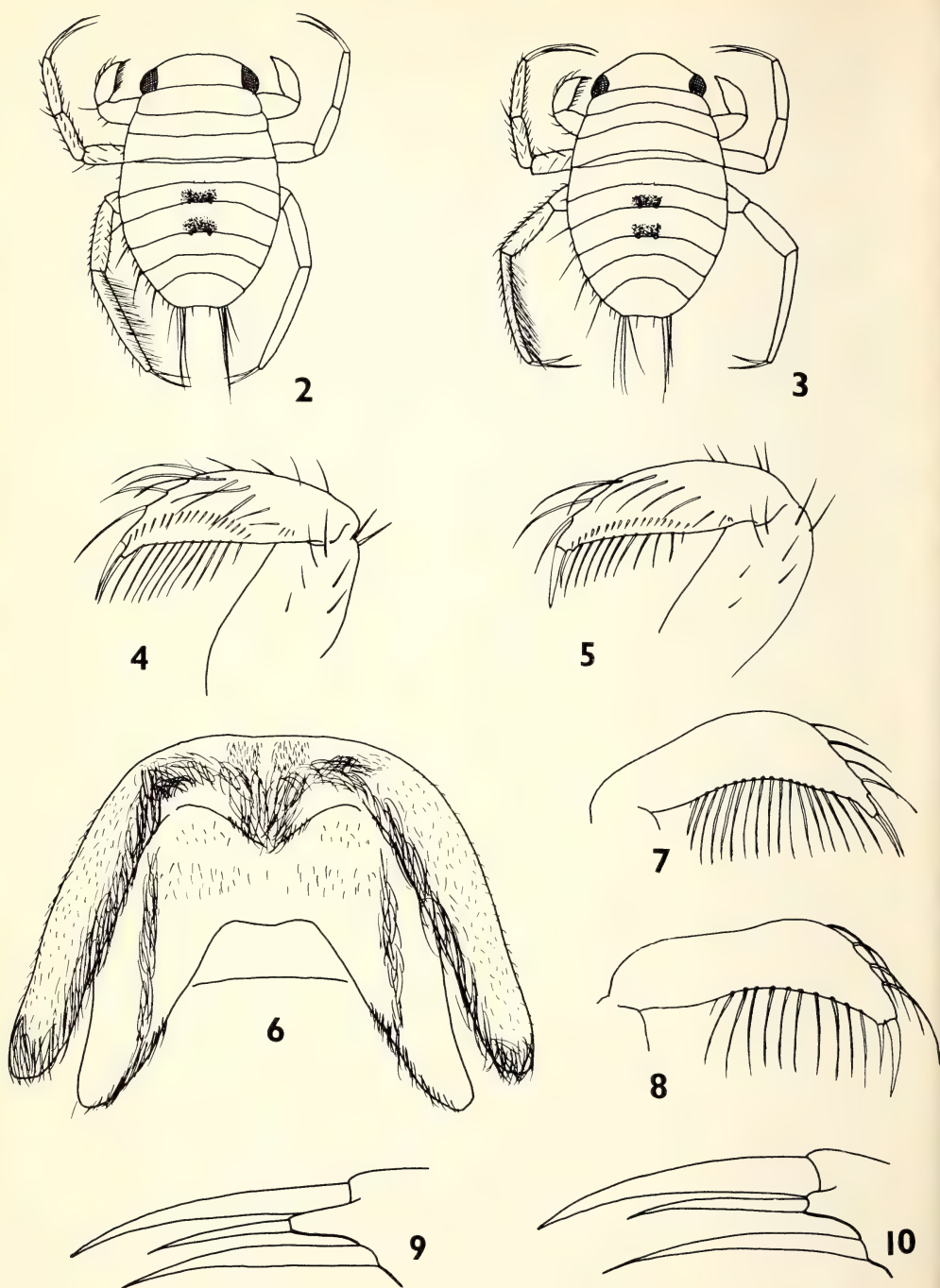
FIRST INSTAR (Figs. 2, 4, 11-12): pala with 12 lower palmar bristles; fore femur anteriorly with 4 spines; hind femur with 5 long hairs dorsally, 4 short spines posteriorly and 3 short spines anteriorly; hind tibia with 10 moveable spines dorsally.

SECOND INSTAR: pala with 14 lower palmar bristles; fore femur anteriorly with 4-5 spines; hind femur with 5 long outstanding hairs and a slender apical bristle dorsally, posteriorly with 4-6 short spines and anteriorly with 3-4 slender spines; hind tibia with 10-11 moveable spines dorsally, these all of similar size.

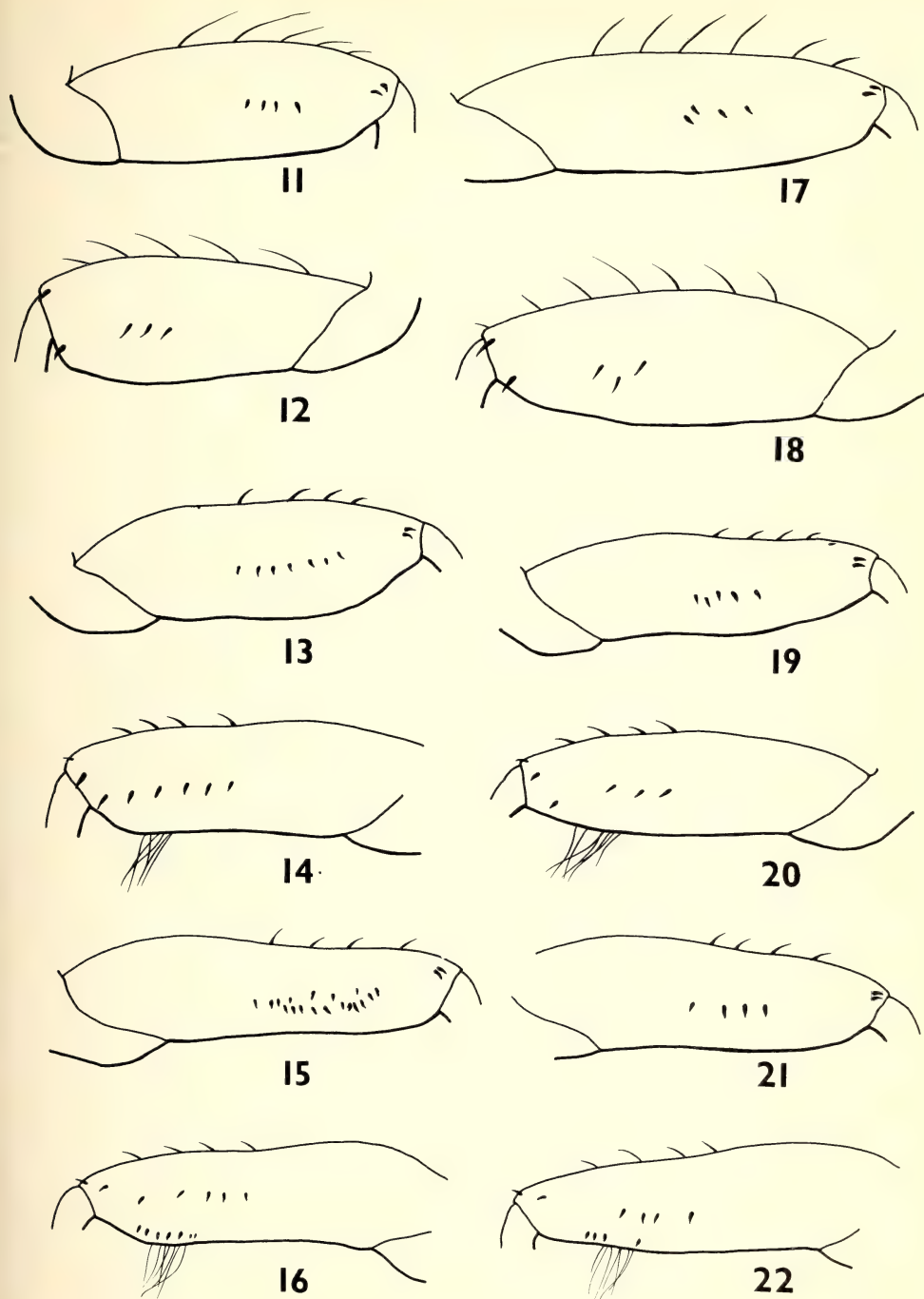
THIRD INSTAR (Figs. 13-14): pala with 14-17 lower palmar bristles; fore femur with 6-8 spines anteriorly; hind femur with 4 short bristles dorsally, 5-8 short spines posteriorly and 4-5 short spines anteriorly; hind tibia dorsally with 12-16 moveable spines, the basal 1-4 shorter than rest.

FOURTH INSTAR: pala with 18-19 lower palmar bristles; fore femur with 13-14 spines anteriorly; hind femur with 4 short bristles dorsally, 7-11 short spines posteriorly and a row of 4-5 short spines anteriorly; hind femur antero-ventrally with 4-5 short spines at base of subapical tuft of hairs; hind tibia dorsally with 14-16 moveable spines, the basal 2-4 shorter than rest and often paired.

FIFTH INSTAR (Figs. 7, 15-16): pala with 18-20 lower palmar bristles; fore femur with 16-22 spines anteriorly; hind femur with 4 short bristles dorsally, 12-26 posteriorly and 3-7 anteriorly; hind femur antero-ventrally with 4-7 short spines at base of subapical tuft of hairs; hind tibia dorsally with 15-19 moveable spines, the basal 3-5 being shorter than rest and usually paired.



Figs 2-10—2, First instar larva *C. bifida*; 3, First instar larva *C. expleta*; 4, Anterior view of pala of first instar *C. bifida*; 5, Anterior view of pala of first instar *C. expleta*; 6, Dorsal view of meso and metanotum of fifth instar *C. bifida*; 7, Posterior view of pala of fifth instar *C. bifida*; 8, Posterior view of pala of fifth instar *C. expleta*; 9, Anterior view of apex of pala of fourth instar *C. bifida*; 10, Anterior view of apex of pala of fourth instar *C. expleta*. [Drawings not to same scale.]



Figs. 11-22—Hind femur of larval instars. 11-16, *C. bifida*; 17-22, *C. expleta*; odd numbers posterior view, even numbers anterior view. 11-12, First instar *C. bifida*; 13-14, Third instar *C. bifida*; 15-16, Fifth instar *C. bifida*. 17-18, First instar *C. expleta*; 19-20, Third instar *C. expleta*; 21-22, Third instar *C. expleta*.
[Drawings not to same scale.]

Table 1. Structural characteristics of larval instars of C. bifida and C. expleta LA = length from anterior of mesonotum to end of abdomen; measurements are the mean of 10 insects; spine counts the range of 10 insects.

Species	Instar	Lower palmar	Spines on		Ventral	Anterior	Posterior	Spines		Head	Length	Abdomen
		bristles	fore femur	Anterior				hind tibia	width			
bifida	1	12	4		0	3	4	10	0.75 mm.	1.15mm.	0.90 mm.	
	2	14	4-5		0	3-4	4-6	10-11	1.00	1.70	1.33	
	3	14-17	6-8		0	4-5	5-8	12-16	1.40	2.65	1.65	
	4	18-19	13-14		4-5	4-5	7-11	14-16	1.75	3.35	2.20	
	5	18-20	16-22		4-7	3-7	12-26	15-19	2.25	5.20	2.45	
expleta	1	10-11	4		0	3	4	10	0.75	1.30	0.93	
	2	11	4		0	5	5	12	1.00	1.95	1.15	
	3	11-12	4-6		0	3-5	4-5	13-14	1.30	2.65	1.60	
	4	11-12	9-13		3-6	3-4	3-6	14-17	1.65	4.00	1.85	
	5	11-12	14-27		3-7	2-4	4-6	15-17	2.15	5.60	2.40	

(5) Descriptions of larvae of *C. expleta*

The descriptions below follow the plan used for *C. bifida* above. Table I summarizes the main taxonomic characters.

FIRST INSTAR (Figs. 3, 5, 17-18): pala with 10-11 lower palmar bristles; fore femur with 4 spines anteriorly; hind femur with 6 long hairs dorsally, 4 short spines posteriorly and 3 slender spines anteriorly; hind tibia dorsally with 10 moveable spines.

SECOND INSTAR: pala with 11 lower palmar bristles; fore femur with 4 spines anteriorly; hind femur with 5 long outstanding hairs and a pre-apical bristle dorsally, 5 short spines posteriorly and 5 short spines anteriorly; hind tibia dorsally with 12 moveable spines.

THIRD INSTAR (Figs. 19-20): pala with 11-12 lower palmar bristles; fore femur with 4-6 spines anteriorly; hind femur with 4 short bristles dorsally, 4-5 short spines posteriorly, 3-5 short spines anteriorly; hind tibia with 13-14 moveable spines dorsally, the basal 3 shorter than rest.

FOURTH INSTAR: pala with 11-12 lower palmar bristles; fore femur with 9-13 spines anteriorly; hind femur with 4 short bristles dorsally, 3-6 short spines posteriorly and 3-4 short spines anteriorly; hind femur antero-ventrally with 3-6 short spines at base of subapical tuft of hairs; hind tibia with 14-17 moveable spines dorsally, the basal 3-5 shorter than rest.

FIFTH INSTAR (Figs. 8, 21-22): pala with 11-12 lower palmar bristles; fore femur with 14-27 spines anteriorly; hind femur with 4 short bristles dorsally, 4-6 short spines posteriorly and 2-4 short spines anteriorly; hind femur antero-ventrally with 3-7 short spines at base of subapical tuft of hairs; hind tibia dorsally with 15-17 moveable spines, the basal 4-5 shorter than rest and often paired.

(6) Duration of immature stages.

The duration of the embryonic development of *C. bifida* from White Lake has been determined for eggs

Table II—Duration of larval instars of *Cenocorixa bifida* in White Lake water, at 20°C and fed every other day on *Artemia salina*.

Instar	Duration
First	4-5 days
Second	4-5
Third	4-5
Fourth	5-7
Fifth	6-9
Total	23-31

laid in White Lake water and at temperatures of 10°C and 20°C. The duration of the larval instars at 20°C has also been measured (Table II).

At 20°C the eggs took 7-9 days to hatch, while at 10°C they took 44-46 days to hatch. The larval period at 20°C took 23-31 days.

DISCUSSION

Hungerford (1948) has given a figure (p. 13) of the various shapes of eggs in the Corixidae. Both the shape of the egg and the mode of attachment to the substrate is variable. While in the Micronectinae the eggs are elongate and attached longitudinally to the substrate without a special attachment disc, those of the Corixinae are characteristically top-shaped with a button-like attachment disc, borne at the end of a stalk of varying length. The chorion is also variable in surface texture, being smooth or with surface projections. The eggs of *Cenocorixa* are thus typical of the subfamily Corixinae.

Cobben & Pillot (1960) have considered the characteristics of importance in the identification of the fifth instar larvae of *Micronecta*, *Cymatia*, *Corixa*, *Hesperocorixa*, *Glaenocorixa*, *Sigara*, *Arctocorixa* and *Callicorixa*. I can find no description of the larvae of *Cenocorixa* in the present literature. It is evident that the latter instars of *Cenocorixa* are very similar to those of the genera *Sigara*, *Arctocorixa* and *Callicorixa* in the pubescence on the mesonotum.

The character of the apical spine of the pala and the prominence at the base of the apical lower palmar bristle serves to separate larvae of *C. bifida* from those of *C. expleta*. The larval instars are also easy to key out in each species.

The study of *Cenocorixa* suggests that it should be possible to key out the last three larval instars of most Corixid species, since the characters of the fifth instar are usually also found in the third and fourth instar. However, the first two instars lack many of these essential characters, and may prove extremely difficult to identify when a mixture of species occur together.

The great transformation between the second and third instar larvae in *Cenocorixa*, also occurs in other Corixidae, for example *Palmocorixa buenoi* Abbott (Hungerford, 1919). Not only does this involve the external characters cited, but there is also great changes in the internal anatomy at this time.

The duration of the immature stages in *C. bifida* at 20°C and fed on *Artemia salina* every other day, is 23-31 days. Since it is possible to lengthen the egg from 7-9 days at 20°C to 44-46 days at 10°C, it seems likely that the larval instars would also take much longer to develop at lower temperatures, and so the life cycle at different times of year would not occupy the same developmental time period. Griffith (1944) reports 35 days as the developmental time for *Ramphocorixa acuminata* (Uhler) and 36 days for *Corisella edulis* (Champion), but notes a great variation in rearing experiments. These differences could have been due to different feeding rates and/or different temperatures: no temperature data are given in the paper.

Acknowledgements

This research was carried out while in receipt of grants from the National Research Council of Canada and the University of British Columbia.

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A BRITISH COLUMBIA RECORD FOR *Xenos peckii* KIRBY

A male *Polistes fuscatus variatus* Cresson parasitized by *Xenos peckii* Kirby was among various wasps collected August 5, 1947 after they had settled for the night on mullein, *Verbascum thapsus* L., 2 miles south of Vernon, B.C. The parasitized wasp had two male strepsipteran pupae protruding from its abdomen, one laterally from between the 5th and 6th terga, the other ventrally from be-

tween the sterna of the same segments. The wasp and the parasites were identified in 1958 by Dr. R. M. Bohart, University of California, Davis, Calif. One of the parasites is in the collection of the University of British Columbia, Vancouver, B.C.

HUGH B. LEECH,
Calif. Academy of Sciences,
San Francisco, Calif.



In Memoriam

GEORGE JOHNSTON SPENCER

Jan. 16, 1888; July 24, 1966

This valiant soldier, this scholar, this leader and inspirer of men who became a legend in his own time, ever ready for a jest, mocked at his own infirmity even as death beckoned. Defying the inevitable, he continued his scholarly work so that posterity might be richer for his having come this way. It is with deep regret that we record his passing.

Professor Spencer was born in South India January 16, 1888. After receiving his early education in Bangalore, he attended the Regent Street Polytechnic Institute in London, and the University of Manchester. Coming to Canada in 1908 he obtained the B.S.A. degree from the Ontario Agricultural College in 1914. As an officer with the Canadian Expeditionary Force in World War I he was cited for valour. Returning to studies, he obtained the M.S. degree from the University of Illinois in 1924. The same year he was appointed to the faculty of the University of British Columbia where he taught general zoology, histology and entomology until his retirement in 1956. Reappointed as a special lecturer in 1957 he gradually phased out his teaching duties while devoting more time to research and professional consulting.

Professor Spencer was renowned as a teacher who infused his students with some of his own special kind of enthusiasm. His lectures were memorable for his vivid word pictures, his dramatization with pantomime and his amusing allegories. His well-judged humour occasionally burst forth in startling contrast to his quiet, though audible, delivery. Testimony of his inspiration to disciples is to be found in the success achieved by numerous former students.

As a public lecturer he was always in popular demand. With an appearance and manner which at once com-

manded attention and respect, he gradually brought listeners to the edge of their seats, waiting for the next revelation of the wonders of nature or the next rib-tickling Spencerism.

As a scientist he directed much of his energy to assembling a representative collection of the insect fauna of British Columbia. In recognition of this work he was honoured by his former students who sponsored the equipping of a room to be known as the Spencer Entomological Museum. On the basis of many years of research among the sun-drenched hills of Kamloops, Professor Spencer published a significant work on ecology of grasshoppers. He devoted much time to the study of external parasites of birds and mammals of British Columbia. Publication of his main works, interrupted by his death, will be brought to completion for him by Dr. G. G. E. Scudder. He contributed many papers on diverse insect pests of man, of man's clothing, his dwellings, and his domestic pets. He was also knowledgeable on "mental insect attacks," a condition otherwise known as entomophobia.

Professor Spencer was, in the words of Dr. H. R. MacCarthy, "a source of strength to the (Entomological) Society (of B.C.), and one of its most ardent supporters. His colourful presentation of papers was a highlight of the annual meeting." His eminence was recognized by his being invited as the keynote speaker at the Centennial celebrations in Ottawa in 1963. The British Columbia and Canadian Entomological Societies awarded him honorary membership, and the American Society bestowed a Fellowship on him.

With skill, patience, tact and good humour, he served the public with his counselling on insect problems. Most of his service was *gratis*, as he dealt with all manner of problems, both real and imaginary, brought to him by all manner of people from the most humble to the most haughty,

and from the unwashed to the over-scrubbed.

He was a kindly, generous-hearted man who liked people, adored children and was fond of animals. He was a devoted husband to his wife Alice, loving father to his daughter Ann, and proud grandfather to his three grandchildren, and all respond-

ed with warm affection. Throughout his hours of greatest trial, Mrs. Spencer remained steadfastly and reassuringly by his side.

Professor Spencer will long be remembered.

K. GRAHAM
October 11, 1966

GEORGE AUSTIN HARDY (1888-1966)

The all-round naturalist of a generation ago was a very special type of person. He was one who was well-versed in all phases of the out-of-doors and at the same time was an authority in one or two special fields. He could name almost every tree, shrub or flower in the area that he roamed and could identify every bird and insect that came to notice. At the same time he could interpret the patterns of life that flowed by in terms of rocks, soil and climate that made up the physical world around him.

Such a person was George Austin Hardy. Stimulated by direct contact with a countryside rich in living things he developed a keen interest in nature as a youth in the Glasgow area where he was brought up. In those days, more than 60 years ago, formal training in natural science was not easy to come by but this lack was offset by living in an area relatively unspoiled by settlement and by association with naturalists who were willing to offer help and encouragement.

After receiving some training as a taxidermist and having taken some courses in biology at Glasgow Technical School Hardy emigrated to Canada where he maintained his interest in natural history while homesteading in Alberta. In time he returned to Britain and worked for a period as a taxidermist, first in London and then at the Essex Museum. But Canada still had an appeal so he returned to the old homestead in Alberta where he made extensive collections of plants, birds and mammals for the

Essex Museum.

Eventually he moved to the Coast and after trying his hand at several jobs he joined the staff of the Provincial Museum in 1924 as Assistant Biologist, a post he occupied for 4 years. After an interlude spent partly in Alberta and partly on Vancouver Island he rejoined the Museum staff in 1941 as Botanist. There followed his most productive period until his retirement in 1953.

No matter where he was located George was fascinated by the whole gamut of nature. The plant association characteristic of the various biotic areas of the province were a constant source of delight and a topic of study, and the communities of living creatures along the sea-shore regularly intrigued him.

He was particularly interested in insects and a great part of his life was devoted to their study. For many years he assiduously collected and worked over the Cerambycidae of the province and eventually became an authority on this particular group of wood-boring beetles. They remained his first love and continued to interest him through the years.

While most of his time at the Museum was taken up with herbarium work he also took care of the entomological needs of the institution and devoted most of his spare time to collecting and studying insects around his home in Saanich.

Field work in various parts of the province gave him opportunity to widen his scope and his lanky frame clad in short pants and armed with a butterfly net and a vasculum star-

tled the natives in many out-of-the-way places.

As the possibility of making new discoveries among the wood-borers lessened he became engrossed with studying the life histories of our less well-known moths and over the years he produced a series of papers on these insects, particularly during his retirement period.

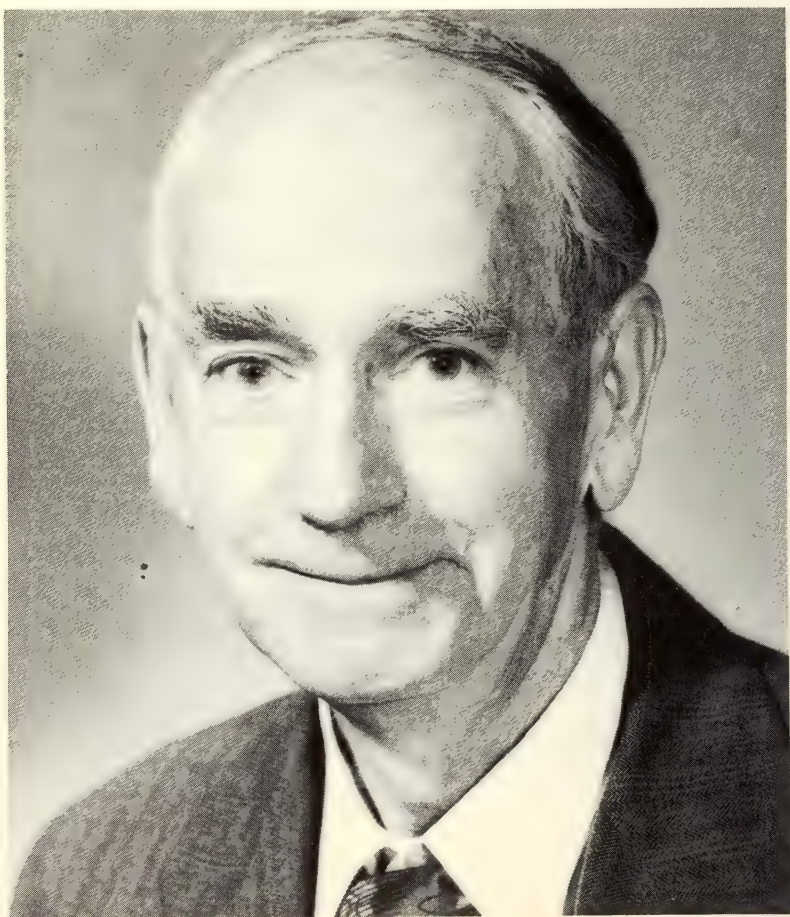
To further these studies he became expert in photographing his subjects. A fine lot of colour pictures and a most extensive collection of exquisitely mounted insects, now in the Museum collection, attest his skill and patience.

Naturally a shy man he tended to avoid meetings and other social gatherings but he became a faithful mem-

ber of the Victoria Natural History Society and served as President from 1949 to 1950. He was elected an Honorary Life Member in 1961.

During his time he published more than 80 articles, reports, scientific papers or popular accounts dealing with a great variety of topics. Foremost among his subjects were insects and many of his life history accounts have appeared in the Proceedings of the Entomological Society of British Columbia. Much of his popular writing had to do with fungi and native plants and his last publication, co-authored with his wife, Winifred, featured wild-flowers of the Pacific Northwest, a part of the world he knew so well.

—G. CLIFFORD CARL.



EDMUND PETER VENABLES
(1881-1966)

At the age of 85, Peter Venables died in the Vernon Jubilee Hospital on 19th October, 1966. He was one of the founders of this society.

Born in Hampshire, England, in 1881, he moved with his family to Manitoba at the age of four. Here they homesteaded but after a few years moved back to England where Peter received a sound education at Hurstpierpoint, near Brighton. At the age of 13 Peter and his family again came to Canada, this time to Coldstream. An adventurous youth included explorations in the Cariboo and service as a naturalist in Colombia, South America.

He was 33 when World War I broke out. He joined the London Yeomanry, was wounded at Gallipoli and also served in Egypt. In 1918 he

was invalided out of the army, and he married in 1919. In 1920 he was hired as an entomologist by the federal Department of Agriculture, working out of the Vernon Court House. For 27 years he served the fruit-growers of the Okanagan Valley, retiring in 1946, to continue living in Vernon.

Peter always had wide and varied interests, the best-known of which was writing poetry. His verses were never unkind and were usually witty. He was made an honorary life member of this society in 1960, and retained an interest in natural history and things entomological to the last. He leaves his widow in Vernon, and a son, Rev. A. P. Venables, in Derbyshire, England.

—D. A. Ross.

NOTICE TO CONTRIBUTORS

Since this society no longer has any support except from subscriptions it has become necessary to institute a page charge. This has initially been set at cost: \$12.00. In other respects policies remain parallel with those of the Canadian Entomological Society. The page charge includes all extras except coloured illustrations, provided that such extras do not comprise more than 40% of the published pages. Coloured illustrations will be charged directly to the author. Authors, not attached to universities or official institutions, who must pay these charges from their personal funds and are unable to do so, may apply for assistance when submitting a manuscript.

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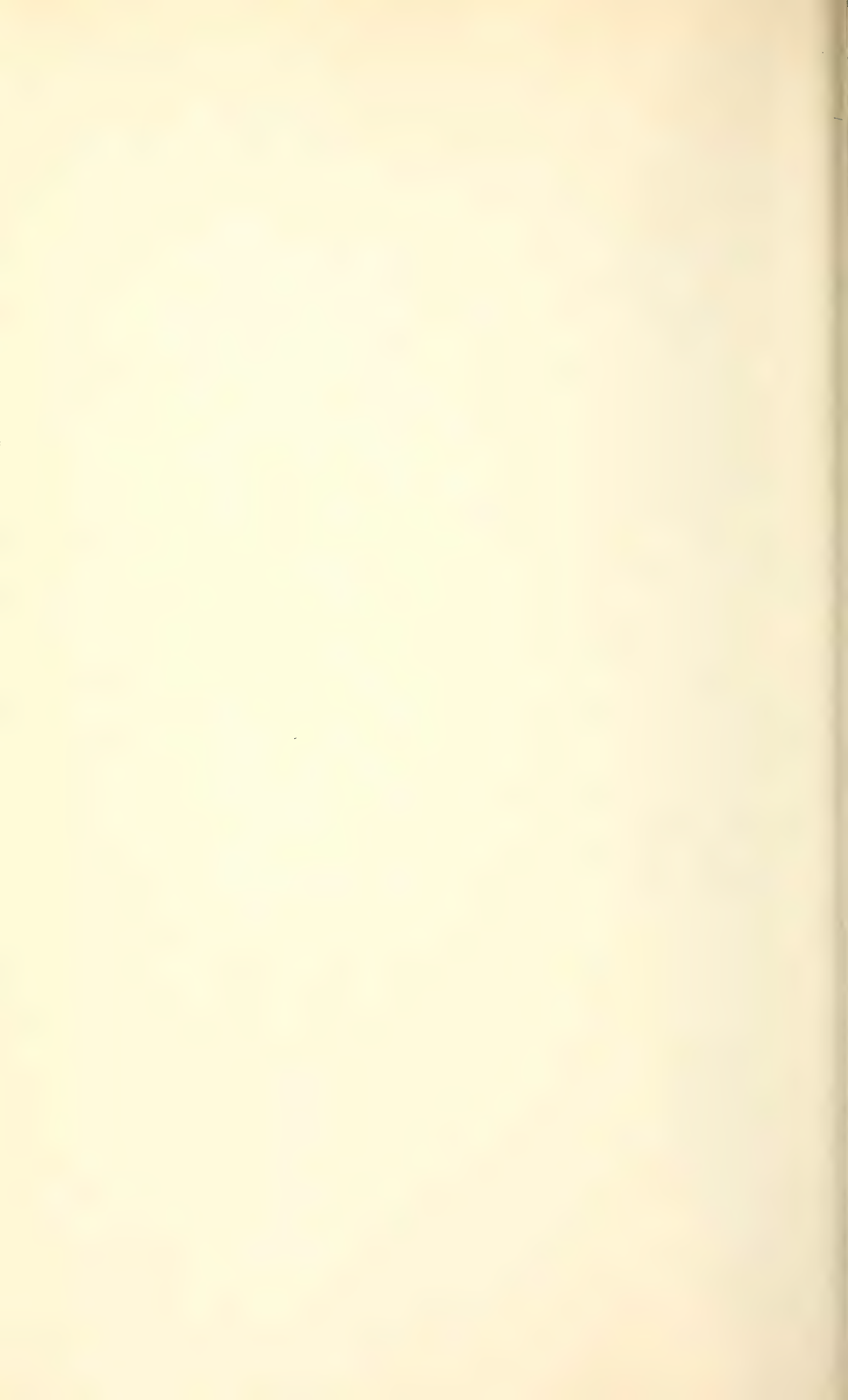
of the Entomological Society of British Columbia, nor is it mandatory, although preferable, that authors be members of the society. The chief condition for publication is that the paper have some regional origin, interest, or application.

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may be on a sheet. Photographs should be glossy prints of good size, clarity and contrast. Line drawings should be in black ink on good quality white paper.

The style, abbreviations and citations should conform to the *Style Manual for Biological Journals* published by the American Institute of Biological Sciences.





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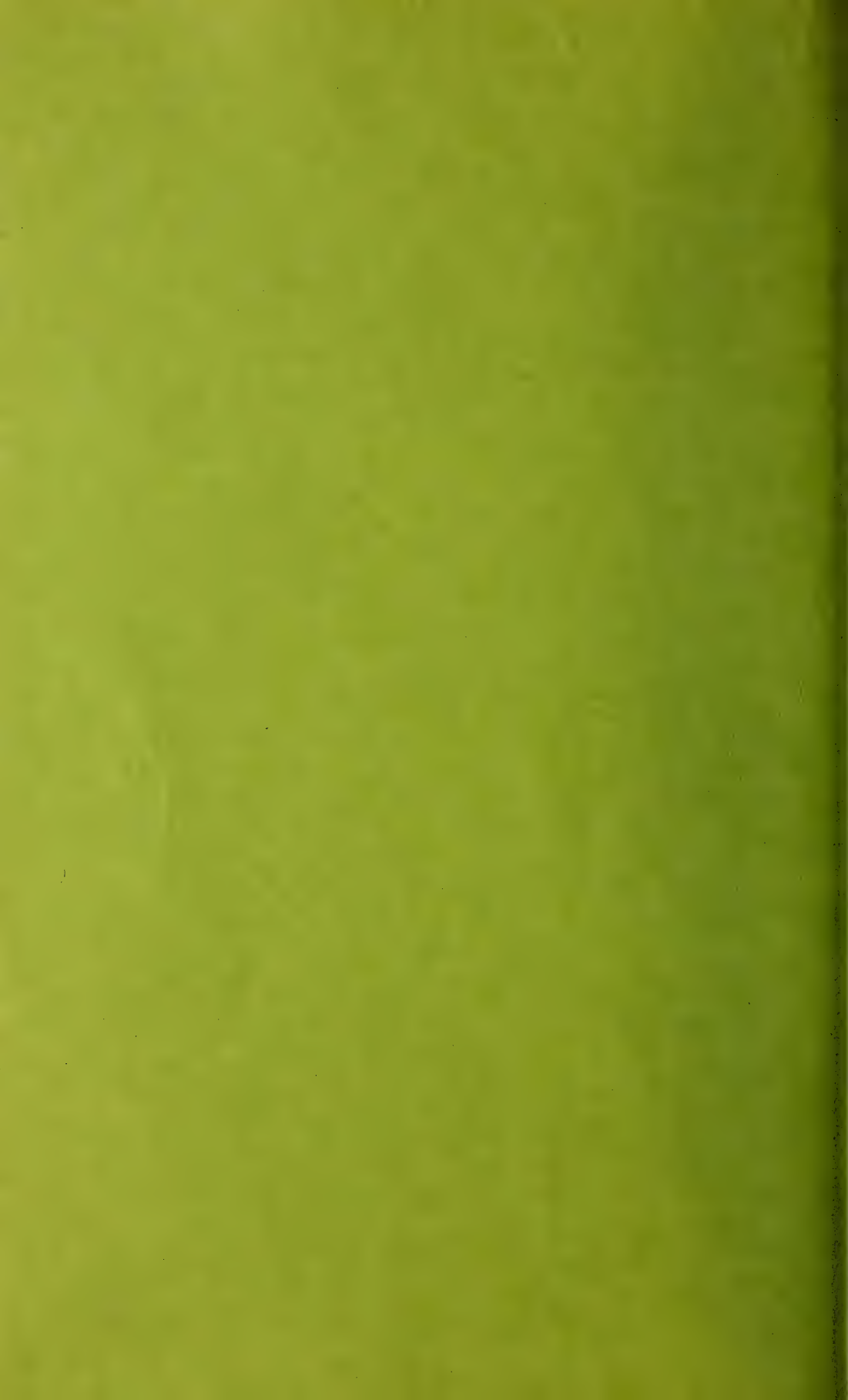
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This copy of the Journal of the Entomological Society of British Columbia comes to you as a Centennial project of the Society, and by courtesy of the editor of the Canadian Entomologist.

The Journal was published for 62 years as the Proceedings of the Entomological Society of British Columbia. It has long since ceased to be a true proceedings in that presidential addresses, and the proceedings and transactions of the Society were not reported. Contributions are reviewed before publication so that it was fitting that the policy be recognized by the change of name in 1966.

Memberships and subscriptions are invited. An application form will be found on page 69 of the Journal.

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THE PERFORMANCE, PHYTOTOXICITY AND PERSISTENCE OF THREE PETROLEUM OILS FOR CONTROL OF THE PEAR PSYLLA^{1,2}

HAROLD F. MADSEN and K. WILLIAMS

ABSTRACT

Good control of the pear psylla, *Psylla pyricola* Foerster, was obtained with two of three petroleum oils tested under field conditions. Each oil was applied three times during the season, once in the delayed dormant stage and twice in the summer. Oil B (vis. 145 S.S.U.) and oil C (vis. 70 S.S.U.) provided seasonal control. Oil A (vis. 71.7 S.S.U.) did not give satisfactory control because of poor kill of pear psylla adults.

All three oils caused enlargement and suberization of the bark lenticels on Bartlett pear trees. There was no significant injury to foliage. Oil treated fruit was equal in quality to fruit from a standard treatment.

The three oils persisted upon foliage for more than 35 days after treatment. Oils A and B showed no loss from the initial deposit. Oil C had a higher initial deposit but this deposit declined 36 per cent after 8 days.

INTRODUCTION

The resurgence of interest in the use of petroleum oil for control of the pear psylla, *Psylla pyricola* Foerster, is partly due to the problem of resistance and partly to the possibility that oils may fit into an integrated control program. Smith (1965) in New York has shown that oils are promising for early season control of the pear psylla. The complexities in evaluating oils because of phytotoxicity and the wide range of oil specifications have been indicated by Howitt and Pshea (1965).

Studies in British Columbia by Madsen and Williams (1967) showed that an oil of 145 viscosity gave better control of the pear psylla with less phytotoxicity than oils of 60 viscosity. The 60-viscosity oils did not persist upon foliage—a desirable property—but the lack of adequate control precluded further evaluation of oils of this viscosity. In 1966 an oil of 70 viscosity, one of 71.7, and the 145-viscosity oil mentioned above were evaluated for pear psylla control, phytotoxicity and persistence on pear foliage.

MATERIALS AND METHODS

The properties of the three oils

are shown in Table 1. Experimental plots were located in a mature Bartlett pear orchard near Kelowna, B.C., which had a high overwintering population of pear psylla. Each plot consisted of 32 trees in a 4x8 block with two replications per treatment. The oils were used in a 3-spray program, one at the delayed dormant stage of tree development (21 Mar.) and two during the summer (6 June and 13 July). All treatments were made with a concentrate sprayer set to deliver 60 gal³ of spray mixture per acre. The oils were used at a dosage of 5 gal of formulated oil per acre⁴.

Perthane, [1,1-dichloro-2,2-bis(p-ethylphenyl) ethane], at a dosage of 1 gal of 4.5 E.C. in the delayed dormant period and 2 gal of 4.5 E.C. in each of the two summer sprays was applied as a standard treatment.

Control was evaluated by counts of pear psylla adults and nymphs at approximately biweekly intervals. Adults were sampled by limb beats with an 18x18 inch⁵ tray held beneath the branch. Each sample consisted of two limb beats per tree. The 12 center trees in each plot were sampled. Nymphs were counted on 100 leaf samples, 50 from senescent leaves and 50 from new growth. An

¹ *Psylla pyricola* Foerster (Hemiptera: Psyllidae)

² Contribution No. 209, Research Station, Research Branch, Canada Department of Agriculture, Summerland, British Columbia.

³ Imp. gallon = 4.55 l

⁴ Acre = 0.405 ha

⁵ Inch = 2.54 cm

TABLE 1.—Specifications of the petroleum oils evaluated for pear psylla control.

Specifications	Oil A ¹	Oil B ²	Oil C ³
Viscosity (S.S.U. at 100°F)	71.7	145	70
50% distillation temperature at 10 mm Hg	443	490	425
Corrected to 760 mm Hg	720	774	699
10-90% distillation range at 10 mm Hg	72	107	95
Average molecular weight	325	385	320
Unsulphonated residue	96.3	94	92

¹ Orchex 796—Humble Oil Company.² Volck Supreme—Chevron Chemical Company.³ Pennsalt Superior—Pennsalt Chemicals Corporation.

untreated check plot was maintained until 6 June. At that time it was necessary to spray the untreated trees with Perthane to prevent excessive damage to the leaves and fruit.

Oil deposits were analyzed by a modified gravimetric method first described by Pearce, Avens and Chapman (1941). Leaf samples consisted of 50 leaves per tree picked at random from five trees in each plot.

Phytotoxicity was determined by field observation of the treated trees. At harvest four boxes each of oil-sprayed pears and pears from the standard treatment of Perthane were picked and placed in standard cold storage. The pears were removed after two months' storage and evaluated for quality.

RESULTS

PEAR PSYLLA CONTROL

Adult and nymphal counts (Fig. 1) show that Perthane gave adequate control of the pear psylla. It was not necessary to apply a second summer spray on 13 July but by 1 Aug. the infestation had increased to a level that required a second summer spray. Oils B and C gave good control, with oil C being slightly better than oil B. Oil A gave poor control and a Perthane spray was applied 13 July to prevent excessive injury to foliage and fruit.

The performance of these oils can be explained by their relative effectiveness against adult pear psylla since they all gave good control of the nymphal stages. It has been shown by several investigators (Smith 1965, Madsen and Williams 1967) that oil

has no residual effect against pear psylla adults, nymphs or eggs, but that residual oil deposits on bark deter egg laying. In the trials at Kelowna oil deposits on leaves did not deter egg laying and the degree of reinfestation depended upon the number of surviving adults. The nymphal population in the oil A plot increased rapidly and required retreatment 3 to 4 weeks after the summer oil spray was applied.

The decline in adult populations in both treated and check plots from 30 Mar. to 18 May was due to natural mortality of the overwintered adults. The rapid rise in adults after 18 May reflected the appearance of the first generation of summer adults. The nymph counts on the check trees were not included in Fig. 1. The counts on these trees were 1655 nymphs per 100 leaves on 18 May and 2160 per 100 leaves on 6 June.

PHYTOTOXICITY

The oil-sprayed trees were examined at frequent intervals for injury. There was little leaf injury although some spotting occurred on sucker growth in the tree centers. The grower applied a nutrient spray containing iron, zinc, manganese and magnesium a week after the first summer spray of oil. This treatment caused a general leaf spotting throughout the orchard and the injury was more apparent on the oil-sprayed foliage. By harvest, bark injury of equal intensity was noticeable on all trees sprayed with oil (Fig. 2). Bark lenticels were enlarged and suberized on the current year's growth and on 1- and 2-year-old wood. The damage is

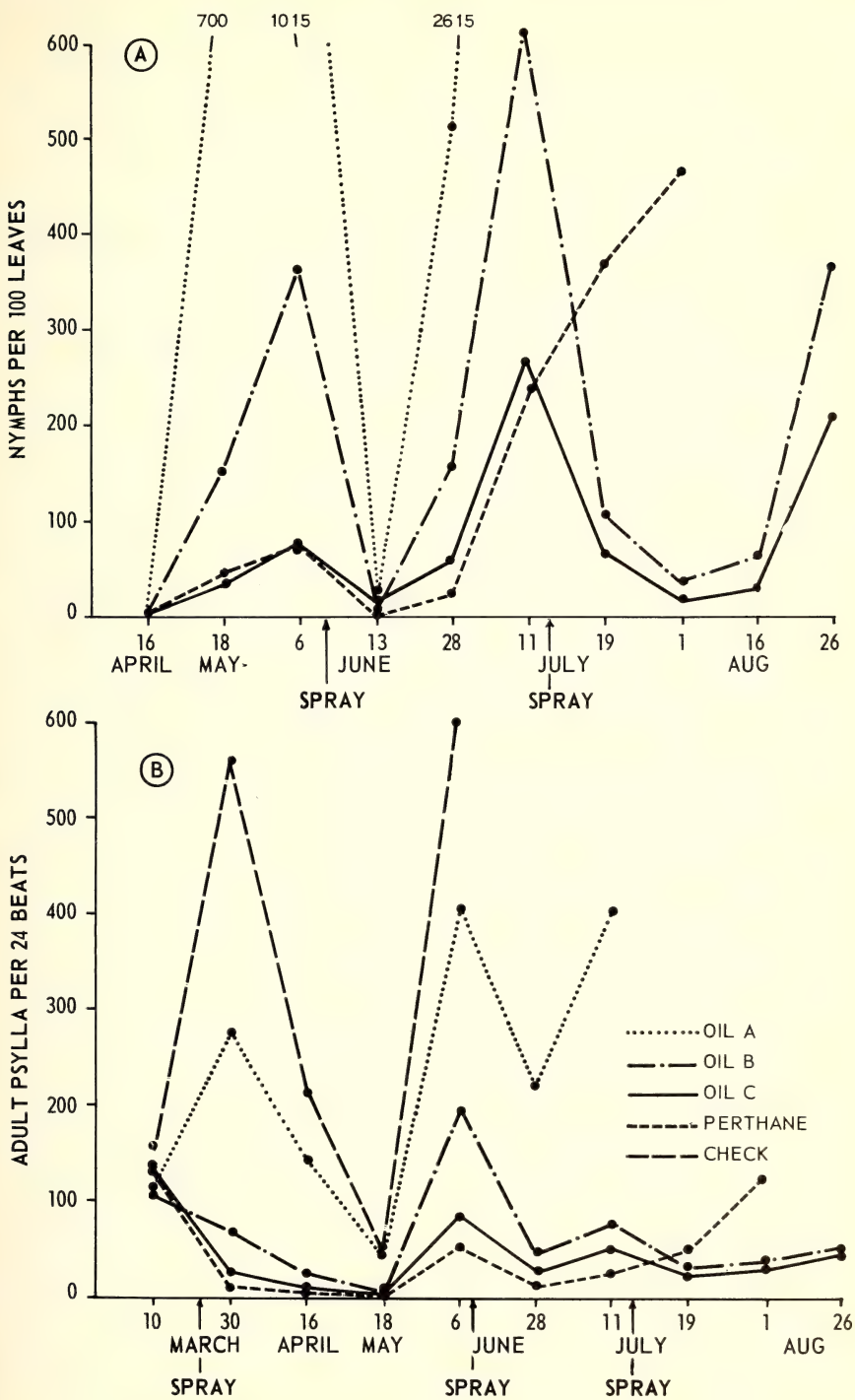


Figure 1.—Pear psylla control with oils—1966.

TABLE 2.—Initial deposit and persistence of oils upon pear leaves
(micrograms per cm²)

Oils	0 day	8 days	15 days	22 days	35 days
Oil A ¹	55	51	50	45	51
Oil B ²	58	61	56	45	66
Oil C ³	84	54	41	41	49

¹ Orchex 796—Humble Oil Company.

² Volck Supreme—Chevron Chemical Company.

³ Pennsalt Superior—Pennsalt Chemicals Corporation.

superficially similar to that caused by egg deposition of the buffalo tree hopper. It is not known when this injury occurs, but the presence of enlarged lenticels on the current season's growth indicates that summer sprays are involved. The fruit from the oil-sprayed and Perthane-treated trees was removed from cold storage on 24 Nov. and examined after being held for eight days at 21.1°C. There was no difference in appearance, ripening, eating quality and condition between the two lots of fruit. Reyneke and Pearse (1945) found that pears dipped in an oil emulsion showed reduced respiratory activity. This resulted in better keeping qualities in storage and an increased juice content.

PERSISTENCE

The analytical data on oil deposits and persistence upon pear leaves are shown in Table 2. Oils A and B showed no dissipation up to 35 days after treatment. Oil C gave a higher initial deposit than either of the other oils and the deposit was reduced by 36% within eight days. After this early loss, there was no further dissipation of oil C. These data are in agreement with the work of Fiori, Smith and Chapman (1963). They showed in laboratory tests that there was no volatilization of oils with an average molecular weight of 300 or above. All three of the test oils fall within this category. The high initial deposit obtained with oil C may be due to the type and amount of emulsifier in the formulation. It has been shown by Marshall (1958) that surfactants will often increase the deposit of spray materials in a concentrate application.

It has been mentioned previously that persistence of oil upon foliage is not a desirable attribute. The presence of oils upon leaves has caused phytotoxic problems when other pesticides are applied after an oil spray (Madsen 1964).

DISCUSSION

These data indicate that certain petroleum oils can provide control of the pear psylla in British Columbia orchards. One weakness of oils is their complete lack of residual action. Unless a high initial adult kill can be obtained, reinfestation will nullify good control of the nymphal stages. The difference in control of adults obtained from oil A compared to oils B and C is difficult to explain. Studies in 1965 by Madsen and Williams (1967) had indicated that oils of 60 viscosity were poor against adult pear psylla. Smith (1965) in New York did not find that oils in the range of 60 viscosity gave poor control. Since oils A and C have similar properties and are both paraffinic in origin, there must be other factors which account for differences in control. One possibility is the wetting properties of the formulated oils. Oil C contained a higher percentage of emulsifier than A and the latter oil may not have wetted the adults sufficiently to obtain control. This point will be investigated further.

Although there was no adverse effect of the oils on fruit or foliage, the enlargement of bark lenticels is of concern. The long-term effect of this symptom on growth and fruit production needs to be determined, and studies to ascertain if altering the time of treatment will reduce or prevent injury are underway.



Figure 2.—Oil-treated Bartlett pear twig (upper) compared to a Perthane-treated twig (lower).

When this study was initiated, it was hoped that oils could be found that would control the pest and dissipate rapidly from treated surfaces. Thus far, all the oils which have given good pear psylla control have been persistent upon pear leaves. Although petroleum oils have drawbacks they do offer promise as a means of control if resistance devel-

ops to the insecticides currently recommended.

Acknowledgements

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NOTE ON DAMAGE TO GRASSES IN THE PEACE RIVER REGION BY THE SPITTLEBUG, *PHILARONIA BILINEATA* SAY, (CERCOPIDAE:HEMIPTERA)

D. A. ARNOTT¹ AND I. BERGIS¹

ABSTRACT

Nymphs of the spittle bug, *Philaronia bilineata* Say, were observed to feed on seed stalks of Merion bluegrass near Dawson Creek, B.C. When nymphs fed on a tuft all the seed stalks turned white and died, regardless of how many nymphs were present. This suggested that the nymphs were phytotoxic or possibly a vector of a pathogenic organism. The damage differed from other types observed and studied. Red fescue was much less affected. Treatment with DDT is recommended.

In 1965 some fields of Merion bluegrass near Dawson Creek, British Columbia, were infested with a spittlebug, *Philaronia bilineata* Say, which caused damage of a type not previously noted in the Peace River region. The damage became evident in the last week of May when the earliest developing seed stalks, with heads partly emerged began to turn

white and appear dead (Fig. 1.). The damage is distinct from the so-called silver top, which occurs later in June when most of the seed heads have emerged, or from cutworm damage in which stalks are cut off at the grass crown.

Spittle masses, hidden by the grass crown, were present on the lower portions of seed stalks. In tufts of grass with more than one seed stalk, one or more nymphs might be pres-

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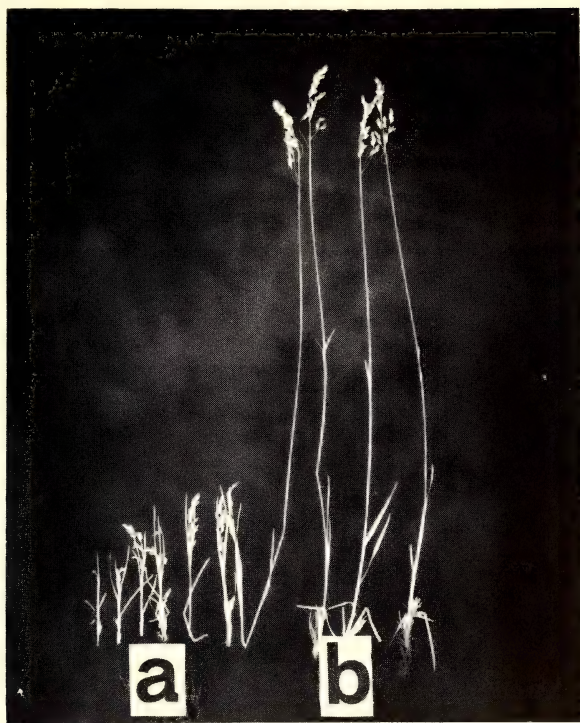


Fig. 1. Merion bluegrass. a. seed stalks killed by *P. bilineata*; b. normal, healthy seed stalks.

ent on each stalk, but in some tufts with several seed stalks only a single nymph was present. Nevertheless, whether one or more nymphs infested a tuft, all the seed stalks in the tuft turned white and died above the roots. These observations suggest that seed stalks may not die from simple feeding by the nymphs but rather from phytotoxemia or because *P. bilineata* is a vector of some pathogenic organism. Byers and Wells (1966) found that damage to Coastal bermudagrass in Georgia and other southeastern states resulted from phytotoxemia caused by the two-lined spittlebug, *Prosapia bicincta* (Say).

In Merion bluegrass adults of *P. bilineata* began to appear about June 9 and in one field were very numer-

ous by June 30, up to 50 or more being taken in one sweep with a 15-inch net. In this field the spittlebug nymphs killed about 10 per cent of the seed stalks. Infestations also occurred in red fescue but damage was much less than in Merion bluegrass.

Although spittlebugs may not be an annual pest of grasses in the Peace River region heavy infestations such as occurred in 1965 could result in economic loss of seed. Treatment of fields with DDT as recommended for control of silver top or cutworms will be effective against spittlebugs.

Acknowledgements

The authors are indebted to the following: L. A. Kelton, Entomology Research Institute, Ottawa, for identity of *P. bilineata* Say, and L. C. Curtis, of this Research Station for the photograph.

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PETROLEUM OILS IN ORCHARD MITE CONTROL¹

R. S. DOWNING

ABSTRACT

Investigations with oil sprays for the control of European red mite, *Panonychus ulmi* (Koch), revealed the following: as dormant sprays, Pennsalt Superior oil was more effective than Shell Neutrol; when either oil was applied at the half-inch green bud stage, the control was better than with dormant applications of the same oil; half-inch green bud sprays of Pennsalt Superior and Imperial 862 were equal in effectiveness. There was no difference in control with a half-inch green bud spray of Volck Supreme, Orchex 796, or Shell Neutrol; summer sprays of Pennsalt Superior oil gave effective control of European red mite.

None of the above applications of oil gave effective control of the McDaniel spider mite, *Tetranychus mcdanieli* McG.

Half-inch green bud sprays of Pennsalt Superior, Imperial 862, Orchex 796 and to a lesser extent Volck Supreme, caused bark lenticel injury to Delicious apple trees but not to McIntosh, Newtown, Rome Beauty, Jonathan, Winesap and Stayman apple trees. Shell Neutrol oil did not produce bark injury.

INTRODUCTION

Marshall (1948) made a study of spray oils on deciduous fruit trees in British Columbia. When comparing oils from California crude he found that a dormant oil of 200-220 SSU at 100° F was more effective against the San Jose scale, *Aspidiotus perniciosus* Comst., and the European red mite, *Panonychus ulmi* (Koch), than an oil of 100-110 SSU. He also found that the heavier oil caused less injury to apple and pear trees than the lighter oil. Based on Marshall's findings the 200-220 SSU oil was and still is recommended in British Columbia as a dormant spray to control certain insects and mites. A combination of this oil with DNOC or lime sulphur was recommended until the mid 1950's to control European red mite but this recommendation was dropped when a pink bud spray of ovex (chlorfenson) or fenson was shown to be more effective (Downing 1958).

During 1960-1963 the European red mite developed tolerance to ovex and fenson. Morestan² subsequently replaced ovex and fenson (Downing 1966a) but further investigations into the use of oils for European red mite

control seemed advisable because there is no evidence of mite resistance to oils (Chapman 1959).

Pearce and Chapman (1947) issued specifications for a "100 second superior oil" and stated that it could be used up to the period when leaves of the fruit buds of apple were exposed about 3/4 inch. Later, Chapman and Pearce (1959) issued specifications for a "70 second superior oil" that could be used throughout the verdant period as a "summer oil". This is a report on investigations carried out at Summerland, British Columbia, with these so called superior type oils and with a 200-215 SSU dormant oil.

METHODS

Most of the sprays were applied by a "Turbo-mist" concentrate sprayer that applied 60 gal. of spray mixture per acre. In some experiments a high-volume handgun sprayer was used. It was operated at 425 psi and the trees were sprayed until dripping. Where the concentrate sprayer was used, each plot consisted of 8 to 12 trees and there were usually 3 replicates per treatment. Estimates of mite densities were made by taking a 20-leaf sample from each of 5 trees per plot. Where the handgun sprayer was used, each plot consisted of 2 trees and there were 2 replicate plots per treatment. Samples of 25 leaves from each

¹ Contribution No. 215, Research Station, Research Branch, Canada Agriculture, Summerland, British Columbia.

² 6-methyl-2,3-quinoxalinedithiol cyclic carbonate 25% wettable powder.

of the 2 trees per plot were taken in the latter case. The leaves were processed by the method of Henderson and McBurnie (1943) as modified by Morgan *et al.* (1955).

Identification of the phytoseiid mites was based on the key of Schuster and Pritchard (1963).

RESULTS AND DISCUSSIONS

Effect On Mites

A preliminary experiment in 1962 compared Pennsalt Superior, a superior type oil of 70 SSU at 100°F, at the green tip stage of McIntosh apple with Morestan at the pink bud stage. The sprays were applied by concentrate sprayer. Records taken in early July showed that the Superior oil at 6 gal. per acre and Morestan at 6 or 8 lb. per acre gave good control of the European red mite but the McDaniel spider mite, *Tetranychus mcdanieli* McG. was not controlled in the oil plot. The McDaniel mite did not increase appreciably on the Morestan plots until the end of July.

In 1964 an experiment was designed to compare: dormant applications of Shell Neutrol, a western dormant oil with a viscosity at 100°F of 200-215 SSU and Pennsalt Superior oil; and half-inch green bud sprays of Pennsalt Superior and Imperial 862 which is a superior type oil with a viscosity at 100°F of 90 SSU. All sprays were applied by concentrate sprayer. The results of this experiment summarized in Table 1 show that: Pennsalt Superior was more effective than Shell Neutrol when both were applied at the dormant stage; the half-inch green bud spray of Pennsalt Superior oil was more

effective than the dormant spray of the same oil; Pennsalt Superior and Imperial 862 were equal in effectiveness when applied at the half-inch green bud stage.

In 1965 applications of Shell Neutrol oil were made at the dormant and half-inch green bud stages of Delicious apple trees by handgun sprayer. Samples of leaves taken on May 26 and June 21 indicated that the half-inch green bud spray was more effective than the dormant spray against the European red mite.

In 1966 a number of apple orchards were sprayed with the following oils: Shell Neutrol, Volck Supreme (140 SSU at 100°F) and Orchem 796 (71 SSU at 100°F). They were applied by handgun sprayer at 2 gal. per 100 gal. or by concentrate sprayer at 6 gal. per acre. All the sprays were applied during the prebloom period from the half-inch green bud stage through to the prepink bud stage.

Table 2 summarizes the results obtained in a 4-acre mature orchard composed of common Delicious and Newtown apple trees. These results, similar to those obtained in the other orchards, show that all oils gave good control of the European red mite and fair control of the apple rust mite, *Vasates schlechtendali* (Nal.).

Effect On Trees

Hikichi and Wagner (1965) noticed that superior oils of 60, 70, or 100 seconds viscosity caused enlargement and cracking of bark lenticels when they were applied in the delayed dormant stage to Delicious apple trees. The bark of McIntosh and Northern Spy was not affected.

In Summerland, similar injury to

TABLE 1.—Average numbers of the European red mite per leaf after spraying Delicious apple trees with 6 gallons per acre of various oils by concentrate sprayer, Summerland, B.C., 1964.

Oil	Stage	European red mites per leaf		
		May 29	July 2	July 22
Shell Neutrol	Dormant *	16.7	sprayed	
Pennsalt Superior	Dormant	2.1	10.8	28.9
Pennsalt Superior	Half-inch green **	0.4	1.4	6.0
Imperial 862	Half-inch green	0.8	4.0	9.8
Check — no treatment		21.8	sprayed	

* Dormant sprays applied March 16, 1964.

** Half-inch sprays applied April 24, 1964.

TABLE 2.—Average numbers of the European red mite, apple rust mite, and predaceous phytoseiid mites per 100 leaves after spraying Delicious and Newtown apple trees at the half-inch green bud stage with 6 gallons per acre of various oils by concentrate sprayer, Kelowna, B.C., 1966.

Oil	European red		Mites per 100 leaves Apple rust		Phytoseiid	
	May 25	July 13	May 25	July 13	May 25	July 13
Shell Neutrol	2	92	305	26350	16	9
Volck Supreme	2	86	545	23310	16	13
Orchex 796	1	74	700	28040	32	44
Check — no treatment	30	sprayed	2247	sprayed	23	sprayed

the bark of Red Delicious apple occurred in 1964, when concentrate applications of either Pennsalt Superior or Imperial 862 were applied at the half-inch green bud stage. The bark of Newtown, Jonathan or Rome Beauty was not affected. Where Pennsalt Superior was applied at the dormant stage the bark injury was hardly noticeable and there was no indication of any injury where Shell Neutrol was applied at the dormant stage.

Shell Neutrol at 2 gal. per 100 gal. was applied in 1964 to one Delicious and one McIntosh apple tree that were in the half-inch green bud stage to determine whether the oil was phytotoxic when applied at that stage of bud growth. No damage resulted then or in the following year when Shell Neutrol was applied to Delicious apple trees at the dormant and at the half-inch green bud stages.

In 1966, Volck Supreme was compared with Shell Neutrol and Orchex 796 because its viscosity is midway between the other two and therefore might be safe to apply at the half-inch green bud stage. These 3 oils were applied to Red Delicious, common Delicious, Newtown, Winesap, Jonathan, and Stayman apple trees. Shell Neutrol did not cause noticeable injury to the bark or foliage. Applied by concentrate sprayer Orchex 796 consistently caused lenticel swelling and cracking on both common and Red Delicious trees but not on the other varieties. Volck Supreme oil caused similar lenticel swelling and cracking where it was applied to Red Delicious by concentrate sprayer but no injury was noted from handgun applications. The bark of the other

varieties including common Delicious was not injured by concentrate or handgun applications of Volck Supreme.

Effect On Predaceous Phytoseiids

An earlier paper (Downing 1966b) showed that both the heavy dormant oil, Shell Neutrol, and the light Pennsalt Superior were low in toxicity to the predaceous phytoseiid mite, *Neoseiulus caudiglans* (Schuster) whether applied in the dormant or half-inch green bud stage of apple. The light oil was also low in toxicity when applied in the summer. These results were confirmed in 1966 when 3 oils were applied during the prebloom period without serious injury to the predaceous phytoseiid mites (Table 2).

Effect of Summer Applications 1962-1966

Pennsalt Superior oil has been the only miticide used since 1962 in a Delicious and McIntosh apple orchard. It was applied during the summers by handgun sprayer at 1 gal. per 100 gal. except on two occasions when the McDaniel mite was so numerous that the oil concentration was increased to 1.5 gal. The oil applications have virtually maintained the trees free of European red mite but have not satisfactorily controlled the McDaniel mite. A total of 10 sprays of oil were applied to the trees during the summers of 1962-1966 and most of these were applied to control McDaniel mite.

Until 1966 no injury appeared on fruit or foliage of Delicious or McIntosh trees although very slight injury to lenticels was evident on Delicious

trees. In 1966, however, after an application of oil on July 9, approximately 15% of the primary leaves of the Delicious apple trees yellowed and dropped. Oil sprays will be continued on these plots to determine if this

symptom was an indication of cumulative oil injury.

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A CERAMBYCID IN A CITY APARTMENT

In April, 1967, I was asked to identify a beetle which had emerged from oak flooring on the eighth floor of a 10-storey apartment building in Vancouver. The building was of reinforced concrete, with a "floating floor" on each level. This type of floor, from top to bottom, consists of 5 16-inch kiln-dried oak, 5/8-inch fir plywood, 3/4-inch air-dried white spruce and 7 16-inch rigid fibre board insulation as a base, all resting on the concrete. The apartment was completed in May, 1966, and the flooring was laid at this time. In December, 1966, a larva was seen in a hole in the floor on the 7th storey. This was noticed by the owners after a tenant had moved, in an area which had been covered by a rug. In March, 1967, a beetle was found emerging from a hole in the floor on the 8th storey. The beetle was identified as the cerambycid *Meriellum proteus* (Kirby).

The life history of this boreal species is not well known. Its host plants

include pine, spruce and balsam fir (Gardiner, 1957) in which the larvae feed in the phloem.

The spruce sub-flooring in this apartment, originating from the Kamloops area, was known to include a few boards with bark attached. This was confirmed when the damaged oak was replaced. These boards must have harbored the beetles. The mature larvae left the phloem, gnawed through the plywood and partially through the oak to pupate just beneath the surface. The adult then emerged prematurely in the spring. The flight period, according to Linsley (1964), is June and July.

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THE EUROPEAN PINE SHOOT MOTH, *RHYACIONIA BUOLIANA* (LEPIDOPTERA: OLETHREUTIDAE), ANOTHER INTRODUCED FOREST PEST

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ABSTRACT

The European pine shoot moth has been reported from Newfoundland to Ontario, the northeastern U.S., Oregon, Washington and British Columbia, where it was first observed in 1927 near Victoria. Two years of intensive survey show that it is now present in the southwestern part of the province on southern Vancouver Island and in the Lower Fraser and Okanagan valleys. Although the pest has only been recorded on ornamental trees in urban areas and on nursery stock, there is a serious risk that it may attack ponderosa and lodgepole pines in natural growing stands. Five specific recommendations are made.

The European pine shoot moth, *Rhyacionia buoliana* Schiffermuller (Lepidoptera: Olethreutidae), which attacks the shoots of immature two- and three-needle pines, was introduced into North America from Europe. It has been reported from Newfoundland to southern Ontario in eastern Canada, the northeastern United States from Lake Michigan to the Atlantic coast, and at a few localities in Washington, Oregon, and British Columbia. The adult, a small orange-brown moth with silvery markings, appears about June and lays its eggs singly or in small clusters on twigs, buds and needles. A week or two later, tiny larvae emerge and feed on the buds and needles until fall when they overwinter within buds or under hardened pitch on the buds. In spring the mature larvae, light-brown caterpillars about $\frac{5}{8}$ inch long with black heads, feed within shoots until May or early June when they become pupae then adults.

Attacked trees rarely die, but may develop spiked, crooked, forked, or bushy tops. In eastern North America, this insect has been responsible for considerable damage to plantations of red pine, *Pinus resinosa* Aiton, Scots pine, *Pinus sylvestris* Linnaeus, Austrian pine, *Pinus nigra* Arnold, and Mugho pine, *Pinus mugo* Turra, in fact most hard pines, including

jack pine, *Pinus banksiana* Lambert, and lodgepole pine, *Pinus contorta* Douglas, have been attacked.

OCCURRENCE IN BRITISH COLUMBIA

The European pine shoot moth was first observed in British Columbia in 1927, in a nursery near Victoria. It was not recorded again until 1938 when about 25 infested trees, mostly lodgepole pine, were found in gardens in south Vancouver. The Canada Department of Agriculture undertook an eradication program in 1939, destroying 88 infested trees. Infested shoots were clipped on other trees, and the trees sprayed with arsenate of lead or nicotine sulphate. The area was re-examined in 1941 and infested shoots found at two locations were destroyed. Little attention was paid to shoot moth from then until 1961 and 1962, when it was detected at Kelowna. In 1963 the shoot moth was found on 30 trees in the Okanagan Valley; 28 trees were imported nursery stock; one was a Mugho pine grown from seed; and one was a mature ponderosa pine, *Pinus ponderosa* Lawson & Son, at the Summerland Experimental Farm. In the same year, the insect was again reported in the Greater Vancouver and Victoria areas in nurseries and gardens. In 1964, it was found at Yarrow, about 50 miles east of Vancouver.

In 1965 and 1966, in co-operation

¹ Department of Forestry and Rural Development, Forest Insect and Disease Survey, Victoria and Vernon, B.C.

with the Plant Protection Division of the Canada Department of Agriculture, a more intensive survey was undertaken to determine the insect's distribution and to appraise the actual or potential hazard to natural stands. Areas of probable occurrence, based on previous surveys, were visited. The results of the survey are summarized in Table 1.

ed nursery stock had been imported recently from Ontario, Holland, and the U.S.A. Lodgepole, Mugho, and Scots pines were the principal species attacked but small numbers of Swiss stone pine, *Pinus cembra* Linnaeus, western white pine, *Pinus monticola* Douglas, Austrian pine, ponderosa pine, red pine, eastern white pine, *Pinus strobus* Linnaeus, and Japan-

TABLE 1. Examinations for European pine shoot moth in British Columbia, 1965-1966.

Type of planting	No. localities examined		No. trees examined		No. trees infested	
	1965	1966	1965	1966	1965	1966
Natural stands	71	89	6,050	9,281	0	0
Gardens, parks, municipal plantings	1,038	2,092	9,153	7,986	26	491
Plantations		2	25,209	3,652	0	2
Nurseries		69	100,170	106,684	101	134

In the Interior, the area of greatest concern, inspections were made at Kamloops, Nelson, Trail, Creston, Grand Forks and in the Okanagan Valley from Vernon south to the U.S. border (Hamilton *et al.*, 1965; Ross *et al.*, 1966). The shoot moth was discovered in one newly established plantation at Westbank in the Okanagan Valley and at nurseries in Oliver, Kelowna, Vernon and Kamloops where Mugho, Scots, and Austrian pines were infested. Infestations were not found in natural stands of lodgepole or ponderosa pine.

In the Coastal area, examinations were made on Vancouver Island from Campbell River south and on the south coast mainland from Powell River up the Fraser River Valley to Lytton (Harris *et al.*, 1965; Holms *et al.*, 1966). The shoot moth was prevalent in parks and gardens throughout the Greater Vancouver and Victoria areas and occurred in the Lower Fraser River Valley at Sumas, Mission City, Yarrow, Chilliwack and Hope. It was in commercial nurseries at Wellington, Victoria, Burnaby, Richmond, Surrey, Aldergrove, Ocean Park, Langley, Yarrow, Sardis, and Pitt Meadows. The infest-

ese black pine, *Pinus thunbergii* Parloure were also attacked. Attacks on sheared Christmas tree plantations and natural-growing lodgepole pine were not observed.

DISCUSSION

The European pine shoot moth is currently confined to ornamental trees in urban areas and to stock in commercial nurseries in the southwest part of the Province. Damage to ornamental trees generally does not result in serious deformation, and is seldom visible on bushy species such as Mugho pine. However, significant damage to forest values could occur if the shoot moth were to spread to forest stands where loss of increment and tree deformity are important. The potential loss may be high in the Interior, where ponderosa pine is an important timber tree. On the Coast the potential loss is relatively low, since lodgepole pine is economically unimportant and is sparsely distributed.

The native hard pines, lodgepole and ponderosa, are susceptible to attack when planted, but the shoot moth has evidently not spread into natural-growing stands. Possibly the insect fails to become established in

natural stands because the trees have not been subjected to unnatural stresses that result from planting or because the natural stands are too distant from focal points of infestation. The majority of infested ornamental plantings are in larger cities, where natural growing pines are uncommon. Knowledge of the effective range of the insect is inadequate, however, and we cannot disregard the possibility of eventual spread to natural stands. Green and Pointing (1962) showed that the moths were potentially capable of flights of several miles and that they can be stimulated to fly under wind conditions favouring their dispersal.

Shoot moth survive winter temperatures that occur on the Coast and probably can persist in some parts of the Interior. Green (1962) reported that, with "cold hardening" and adequate snow cover, shoot moths survive winter temperatures down to approximately -22°F . Although in the Okanagan Valley occasional lower winter minimums have been recorded, favourable temperatures have existed near Okanagan Lake over extended periods. At one station in Kelowna, the minimum temperature recorded over a period of 16 years was -20°F and at another in Penticton the minimum over 58 years was -16°F (Meteorological Branch, Air Services Division, Department Transport (Canada), 1966). Ross (1966) reared nine shoot moth pupae on several recently transplanted caged trees at Vernon during the 1965-1966 winter when temperatures dropped to -4°F .

The European pine shoot moth was accidentally introduced into British Columbia and, like other introduced forest insects and diseases in the Province, such as balsam woolly aphid, *Adelges piceae* (Ratzburg), poplar-and-willow borer, *Sternococcus lapathi* (Linnaeus), lecanium scale, *Eulecanium coryli* (Linnaeus), white pine blister rust, *Cronartium*

ribicola J. C. Fischer and trellis rust, *Gymnosporangium fuscum* Hedwig f. in DC., it probably entered on nursery stock. Shoot moth in B.C. nurseries occurred on trees imported from eastern Canada, the U.S., or Europe, and most of the infested trees in gardens and parks had been recently purchased from nurseries. Movement of their living hosts doubtless affords many pests an ideal opportunity for transport to distant localities. In the spring and fall, when plants are usually moved, detection of dormant insects, often hidden within plant parts, is extremely difficult. Moreover, inadequate inspection of and restrictions on movement of nursery stock enhances the possibility of spread of damaging organisms.

RECOMMENDATIONS

The following safeguards should be considered to prevent possible infestation of economically important trees by European pine shoot moth imported on ornamental pines:

1. Inspections of trees entering the country should be intensified and inspections of trees moved from one province to another as nursery stock should be imposed.
2. Imported stock should be kept under post-entry quarantine for at least 1 year so that symptoms not visible initially could be detected.
3. Requirements for nurseries to control pests on their trees should be more strictly enforced.
4. Pines should be grown locally from seed.
5. An educational programme emphasizing the dangers of introducing forest insect pests should be implemented.

Acknowledgements

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RESISTANCE TO ORGANOCHLORINE INSECTICIDES IN THE TUBER FLEA BEETLE, *EPITRIX TUBERIS* GENT. (COLEOPTERA: CHRYSOMELIDAE), IN BRITISH COLUMBIA¹

F. L. BANHAM and D. G. FINLAYSON

ABSTRACT

Laboratory and field experiments showed that *Epitrix tubensis* Gent. had developed strains that were highly resistant to dieldrin and less so to DDT. Both adults and larvae were resistant to the cyclodiene insecticides. Strains resistant to cyclodienes were centered in the Salmon Arm and Vernon areas. Strains resistant to DDT had a wider range and were present as far north as Pavilion. All tuber flea beetles tested in the province were highly susceptible to diazinon and presumably to other organophosphorus compounds.

INTRODUCTION

In the southern interior of British Columbia the tuber flea beetle, *Epitrix tubensis* Gent., has been controlled effectively since 1953 by incorporating into the soil the cyclodiene organochlorine insecticides: aldrin, chlordane, dieldrin and heptachlor (Banham, 1960). These insecticides gained a ready acceptance and were widely used because one low-cost application gave broad-spectrum insecticidal effectiveness. In 1963, laboratory tests were conducted to determine the susceptibility of *E. tubensis* to dieldrin and DDT. Dieldrin was included because of the reported failure in 1960 of soil applications of the

cyclodiene insecticides to control *E. tubensis* in Clackamas County, Oregon, (Morrison, 1962). DDT was included because it was used in British Columbia as a foliar treatment against this pest after 1948 following investigations by Finlayson and Neilson (1954); it remains an alternative to soil treatments with the cyclodienes.

The first suspicion that resistant *E. tubensis* were present in British Columbia came at harvest in 1964, in the Salmon River Valley. Six growers reported excessive larval tunneling damage in their potatoes in spite of the use of aldrin or dieldrin at recommended rates. This paper reports the initial laboratory experiments in 1963 and further tests in 1965. Data are reported also from a field experiment in the Salmon River Valley in 1965 to confirm the occurrence of resistance.

¹ Contribution No. 214, Research Stations, Research Branch, Canada Agriculture, Summerland, and No. 124, Vancouver, British Columbia.

MATERIALS AND METHODS

Laboratory Exposures

Larvae of this species were not used for the susceptibility tests because they are extremely small and difficult to rear. They are root and tuber feeders that desiccate rapidly on exposure. Field-collected second generation adults were used because of their hardiness, abundance, and ease of handling. The sex ratio is 1:1 (Neilson and Finlayson, 1953), but there are no external sex characteristics, and no attempt was made to determine differences in male and female susceptibility. Collections were made at the peak of emergence from nine major potato growing areas in 1963 and from eight areas in 1965 (Fig. 1.) The beetles were held at 4 to 10°C in screen-topped glass jars and provided with fresh, uncontaminated potato foliage. Prior to testing, beetles from each area were acclimatized in screened cages at 22°C. Active beetles were removed from the cages with an aspirator, anaesthetized with CO₂, and held temporarily in a 150 mm Büchner funnel under a continuous flow of the gas. Anaesthetized beetles were transferred with a brush or forceps to the exposure cages.

In 1963 impregnated papers from two sources were used: the Macdonald Test Kit and the W.H.O. Test Kit². The Macdonald exposure cage consisted of a cardboard Dixie cup with a silk screen lid, a plastic ring, and an impregnated exposure paper that covered the sides and bottom of the cup. This exposed the beetles to contact with the impregnated paper on all but the top, screened surface of the cage. The concentrations of the impregnated papers used were: 0.0, 0.25, 0.5, 1.0, 2.0, and 4.0% DDT in Risella oil. The W.H.O. papers (W.H.O., 1960) were impregnated with: 0.0, 0.1, 0.2, 0.4, 0.8, 1.6, and 4.0% dieldrin in Risella oil. Each was

fitted to the inside of a 40x100 mm cardboard tube with screened ends.

In 1965 the only exposure cage used was the W.H.O. Test Kit, a transparent plastic cage with screened ends. The impregnated papers used included W.H.O. dieldrin papers as described above and also W.H.O. DDT papers with concentrations of 0.0, 0.5, 1.0, 2.0, and 4.0% DDT in Risella oil. In addition, two series of papers prepared at the Vancouver Research Station were used: the first included concentrations of 0.0, 0.125, 0.25, 0.5, 1.0, 2.0, and 4.0% dieldrin in a 1:1 mixture of Risella oil and trichloroethylene; the second included 0.0, 0.0625, 0.125, 0.25, 0.5 and 1.0% diazinon in a 1:1 mixture of acetone and corn oil. The papers were prepared by applying uniformly 2.0 ml of insecticide solution to a 12x15 cm sheet of Whatman No. 1 filter paper placed on a horizontal plane of points. After the more volatile solvents evaporated, each paper was attached to a cord by a paper clip and hung to dry for at least 24 hours before use.

The toxicities of laboratory - and W.H.O.-prepared dieldrin papers were found to be comparable when susceptible and resistant strains of beetles were exposed to each series.

Each replicate consisted of ten beetles per concentration of insecticide. Depending on the number of beetles available, the number of replicates per collection area varied from one to three in 1963 and from one to five in 1965. When there were not enough beetles from one location to complete a replication, those remaining were combined with beetles of similar susceptibilities from three or more areas.

The caged beetles were exposed to the insecticides in a cabinet at 22°C and 75% relative humidity. Exposure periods ranged from one to four hours. Knockdown, or inability to walk normally, was recorded at the end of the exposure. The beetles were then transferred to clean holding tubes containing fresh, uncontaminated

² The Macdonald Test Kit was supplied by Prof. F. O. Morrison, Dept. of Entomology and Plant Pathology, Macdonald College, Ste. Anne de Bellevue, P.Q.; the W.H.O. Test Kit by Dr. R. Pal, Division of Environmental Health, World Health Organization, Geneva.

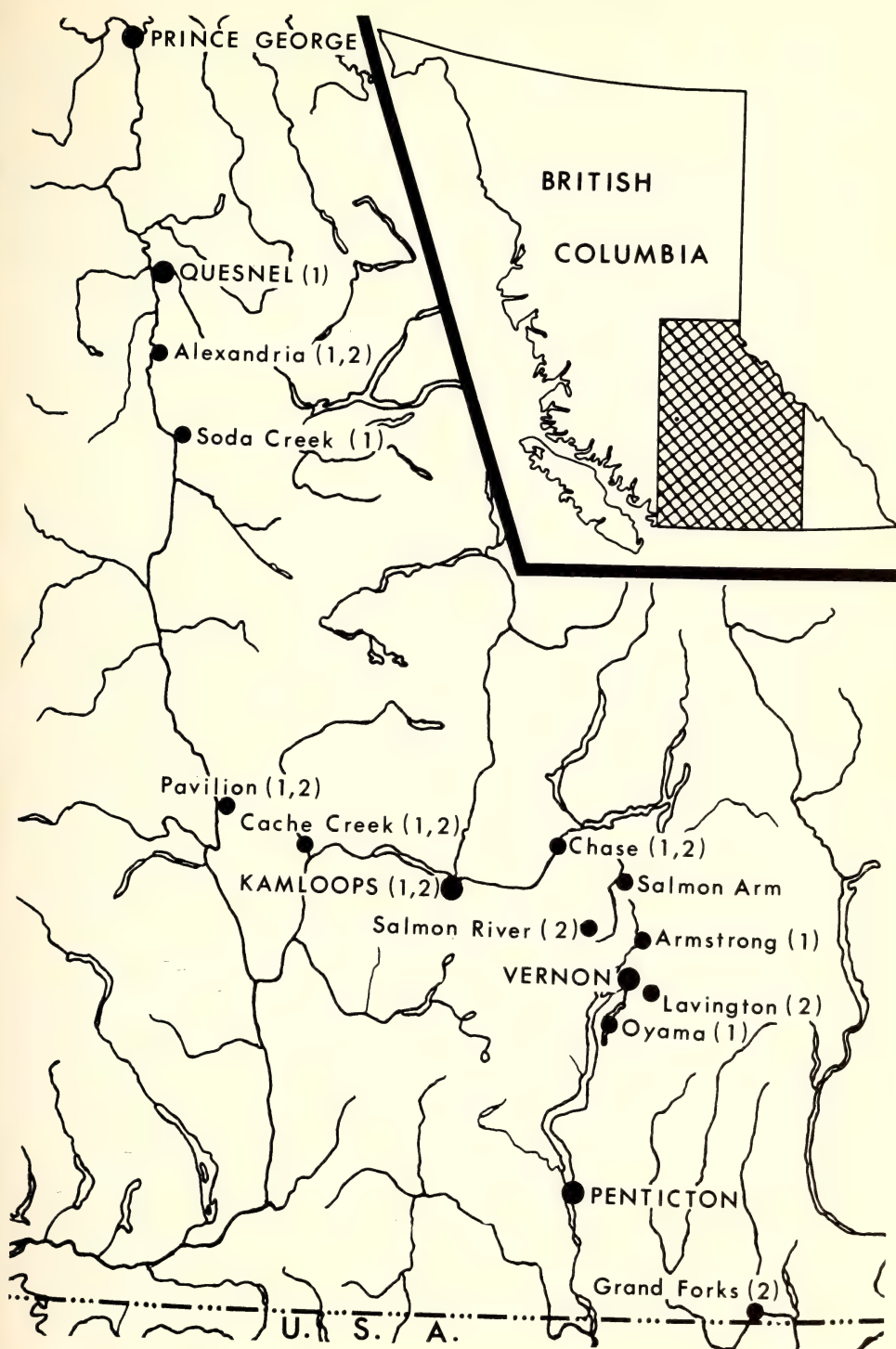


Fig. 1.—Potato growing areas in British Columbia where tuber flea beetles, *Epitrix tuberis* Gent., were collected: (1) 1963; (2) 1965; and (1,2) 1963 and 1965.

potato foliage and returned to the cabinet. Mortality counts were made at the end of a 24-hour recovery period. Beetles unable to walk were counted as dead.

In these tests, beetles from a given locality were considered to be resistant if the slope of the dosage-mortality curve was flat, or if a ten-fold increase in concentration resulted in less than a 20% increase in mortality. Populations showing an increase in mortality greater than 20% but less than 90% at this increased concentration, were defined as tolerant; those with increases greater than 90% were defined as susceptible. The data were averaged. Corrections for natural mortality were made using Abbott's formula (Abbott, 1925).

Field Experiments

In 1965 an experiment to compare aldrin-treated and untreated plots was set out in the Salmon River Valley (Fig. 1). The plots, approximately 24 yd² (22 m²), were replicated four times in randomized blocks. Aldrin 20% emulsifiable concentrate, was sprayed on the soil, at the recommended rate of 4 lb. toxicant acre (4.48 kg ha), prior to planting. The aldrin was incorporated into the soil

to a depth of 3 to 4 inches (7.5 to 10 cm) by discing. Two samples of tubers were taken from the treated and untreated plots: the first, 84 days after planting, was to determine the damage inflicted by first generation larvae; the second, 147 days after planting, was to determine the seasonal damage by first and second generation larvae. To assess damage, a subsample of 25 tubers of a minimum diameter of 1.5 inches (4 cm) was selected from each plot sample. The tubers were peeled to a uniform depth and the number of larval tunnels recorded.

RESULTS

Laboratory Experiments

Knockdown and mortality counts of beetles exposed to DDT, with minor exceptions, were highest at the longest periods of exposure. For any given concentration and exposure, knockdown counts paralleled the mortality counts but at lower levels.

In 1963 (Table 1) there was little, if any, resistance to DDT at Chase, Quesnel, or Soda Creek. However, at Alexandria, Armstrong, Cache Creek, Kamloops and Pavilion the results indicated the first stages of resistance. There was little evidence of resistance to dieldrin.

TABLE 1.—Susceptibility to DDT and dieldrin of adult *E. tuberus* in British Columbia, 1963.

Location	Exposure (hr.)	Mortality (%) ¹ at 24 hr.					
		DDT (%)					
		0.25	0.5	1.0	2.0	4.0	
Alexandria	2	10.0	30.0	10.0	30.0	60.0	
Alexandria	4	20.0	50.0	50.0	90.0	100.0	
Armstrong	4	50.0	50.0	90.0	80.0	80.0	
Cache Creek	4	50.0	0.0	0.0	80.0	100.0	
Chase	2	50.0	60.0	60.0	70.0	100.0	
Kamloops	2	17.0	27.0	37.0	50.0	67.0	
Kamloops	4	40.0	50.0	65.0	90.0	100.0	
Pavilion	2	10.0	10.0	10.0	15.0	30.0	
Quesnel	2	22.2	—	11.1	—	100.0	
Soda Creek	2	20.0	40.0	30.0	100.0	100.0	
Composite ²	4	88.9	66.7	88.9	88.9	100.0	
		Dieldrin (%)					
		0.1	0.2	0.4	0.8	1.6	4.0
Alexandria	4	—	60.0	80.0	100.0	100.0	100.0
Kamloops	1.5	10.0	30.0	60.0	70.0	90.0	100.0
Kamloops	2	0.0	75.0	62.5	87.5	100.0	100.0
Kamloops	4	20.0	70.0	100.0	100.0	100.0	100.0
Pavilion	1.5	3.0	13.0	37.0	80.0	97.0	100.0
Composite ²	2	30.0	0.0	70.0	90.0	90.0	100.0

¹ Average corrected by Abbott's formula (1925)

² Armstrong, Kamloops and Oyama.

By 1965 (Table 2) there was strong evidence of DDT-resistance at Lavington and Salmon River. Of the beetles from eight potato-growing areas, those from Lavington and Salmon River also exhibited a high resistance to dieldrin, probably approaching a homozygous-resistant population. Beetles from Cache Creek and possibly those from Pavilion showed less resistance, or a heterozygous population. Beetles from Alex-

andria, Chase, Grand Forks and Kamloops were still susceptible. The beetles with high DDT and dieldrin resistance, from Lavington and Salmon River, were highly susceptible to diazinon. A composite sample of beetles from Alexandria, Cache Creek, Chase, Kamloops and Pavilion were also equally susceptible.

Field Experiments

At Salmon River, tuber samples taken 84 and 147 days after planting

TABLE 2.—Susceptibility to DDT, dieldrin, and diazinon of adult *E. tuberis* in British Columbia, 1965.

Location	Exposure (hr.)	DDT (%)				
		Mortality (%) ¹ at 24 hr.				
		0.5	1.0	2.0	4.0	
Lavington	1	0.0	10.0	10.0	10.0	
Lavington	2	0.0	0.0	10.0	20.0	
Salmon River	1	0.0	0.0	5.0	15.0	
Salmon River	2	10.0	10.0	0.0	20.0	
Composite ²	1	0.0	23.5	0.0	58.8	
Composite ²	2	0.0	10.0	0.0	60.0	
		Dieldrin (%)				
		0.125	0.25	0.5	1.0	2.0
Alexandria	1	59.5	81.1	97.3	86.5	100.0
Cache Creek	1	30.0	50.0	45.0	50.0	70.0
Chase	1	90.0	95.0	100.0	100.0	100.0
Grand Forks	1	73.9	100.0	100.0	100.0	100.0
Kamloops	1	70.0	80.0	90.0	100.0	100.0
Lavington	1	0.0	0.0	0.0	0.0	5.0
Pavilion	1	30.0	40.0	60.0	90.0	90.0
Salmon River	1	3.1	0.0	3.1	0.0	0.5
		Diazinon (%)				
		0.0625	0.125	0.25	0.5	1.0
Lavington	1	60.0	75.0	90.0	100.0	100.0
Salmon River	1	65.0	90.0	90.0	95.0	100.0
Composite ²	1	80.0	90.0	90.0	90.0	100.0

¹ Average corrected by Abbott's formula (1925).
² Alexandria, Cache Creek, Kamloops and Pavilion.

from untreated and aldrin-treated plots showed little difference in the amount of larval feeding damage. This confirmed the laboratory evidence for cyclodiene resistance in *E. tuberis*. Average numbers and ranges of larval tunnels per tuber from aldrin-treated and untreated plots were as follows:

84 DAYS	Average	Range
aldrin-treated	56.6	11-209
untreated	57.7	9-139
147 DAYS		
aldrin-treated	229.1	27-484
untreated	187.6	7-536

DISCUSSION

It is difficult to determine the

level of resistance in an insect species when the range of concentrations of the test insecticides is restricted by the availability of field-collected specimens. The level should be determined by direct comparison of the LD₅₀ of the suspect strain with that of the normal susceptible strain (Brown, 1958).

From the results obtained in 1963, beetles from Pavilion were resistant to DDT while those from Alexandria, Armstrong, Cache Creek and Kamloops were tolerant. All the beetles from the nine locations sampled in 1963 were susceptible to dieldrin. Suspected resistance at Salmon River in

1964 was confirmed by laboratory tests in 1965. The same tests confirmed resistance at Lavington. The failure of a soil-incorporated application of aldrin in the field experiment showed that the larvae were resistant also. Soil treatments of aldrin or other cyclodiene insecticides normally prevent damage by killing the newly emerged 1st, 2nd and on occasion, 3rd instar larvae while they search in the soil for potato roots or tubers. It was demonstrated that these populations had cross-resistance to DDT, but not to diazinon, and presumably not to other organophosphorus compounds. Beetles from Cache Creek were highly tolerant to dieldrin, and the DDT-tolerance shown in 1963 by beetles from Alexandria, Cache Creek, Kamloops, and Pavilion was reflected in the low mortality counts of the composite sample after exposure to DDT in 1965.

In the interior of British Columbia the tuber flea beetle has developed resistance to DDT and dieldrin in

areas where extensive use of soil-incorporated cyclodiene insecticides commenced in 1953 and 1954 superseding foliar applications of DDT. Use of cyclodiene insecticides, known to be persistent (Banham, 1961), resulted in accumulations of insecticidally active residues in the soil. Since *E. tuberosus* is virtually host specific, the whole population at one location was continually exposed to broadcast or band applications of the current year plus the accumulated residues from previous years. This, coupled with the tendency of growers to shorten the sequence of crop rotation under conditions of concentrated production, subjected this species to increased selection pressure.

It has been shown (Varzandeh *et al.*, 1954) that development of resistance has no apparent effect on the biotic potential of *Musca domestica* L. Results of tuber damage assessments from field plots at Salmon River in 1965 clearly indicate that this applies as well to *E. tuberosus*.

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WOOD- AND BARK-FEEDING COLEOPTERA OF FELLED WESTERN LARCH IN BRITISH COLUMBIA

D. A. Ross¹

ABSTRACT

A list of wood- and bark-feeding Coleoptera reared from western larch, *Larix occidentalis* Nuttall, in 1928-29 and 1965-66, and the range of emergence dates are presented. The only species reared in significant numbers were the wood borers, *Tetropium velutinum* LeConte, *Serropalpus substriatus* Haldeman, *Melanophila drummondi* (Kirby) and the bark beetle, *Dendroctonus pseudotsugae* Hopkins.

In 1928-29 J. R. L. Howell (unpublished data)² reared insects that had infested a felled western larch, *Larix occidentalis* Nuttall, at Trinity Valley, B.C., to determine the species complex of the stump, bole and limbs. The tree, of unrecorded size, was felled in May 1927 and the trunk, limbs, and stump were caged separately on 8 May 1928. Emergence of adult insects recorded daily during the emergence periods until the fall of 1929 are considered here.

Investigations were initiated to determine the species of wood-infesting Coleoptera of economic importance to western larch in British Columbia. Nine samples of infested western larch logs from 1964 logging

operations were caged at Vernon in April and May 1965. Seven additional samples from trees felled in the spring of 1965, were caged in the spring of 1966. Each sample consisted of three 2-foot-long bole sections 8 to 12 inches in diameter. Emergents were collected daily during the 1965-66 emergence period.

Infested logs were collected at Arrow Park, Grand Forks, Mt. Morrissey, Wilson Creek, Howser Ridge, Lumberton, Little Slocan, Sugar Lake, and Cherryville.

The emergence dates (Table 1) probably are earlier than would be expected under stand conditions, since Vernon is at a lower elevation than the collection sites of the logs. Also, emergence ranges probably include the emergence of spring and late summer broods, at least in the case of *Tetropium velutinum*. A neg-

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² In files of Forest Entomology Laboratory, Vernon, B.C.

TABLE 1. Emergence at Vernon, B.C., from 16 samples¹ of western larch logs from various localities in southern British Columbia.

Species	No. samples infested	Range in No. emergents per sample	Emergence range	
			1965	1966
CERAMBYCIDAE				
Anoplodera canadensis Oliv.	1	0 - 1	Jul 21	
Tetropium velutinum Lec.	14	2 - 100	May 20- Aug 6	May 2- Aug 30
MELANDRYIDAE				
Serropalpus substriatus Hald.	8	1 - 55	?	Jun 29- Sep 3 May 2
Xylita livida Sahlb.	1	0 - 1		
BUPRESTIDAE				
Melanophila drummondi (Kby.)	13	3 - 44	May 17- Aug 12	May 26- Jul 29
SCOLYTIDAE				
Dendroctonus pseudotsugae Hopk.	4	3 - 50	Apr 30- May 11 Jun 19	Jun 11 Jul 13- Aug 20
SIRICIDAE (Undet. spp.)	3	1 - 7		

¹ Each sample a total six lineal feet.

ligible number of insects emerged in 1966 from the nine samples caged in the spring of 1965.

Howell (Table 2) reared 13 wood- or bark-feeding species from the stump, 11 from the bole and 8 from the limbs. *T. velutinum*, *Serropalpus substriatus*, *Melanophila drummondi*, and *Dendroctonus pseudotsugae* emerged in significant numbers from the bole. Only the bark beetle *D. pseudotsugae* emerged in quantity from the stump, and *T. velutinum* and *Pissodes schwarzi* Hopk. from the limbs. Most species emerged the first year. The major emergence of *T. velutinum* and *M. drummondi* occurred the first year followed by a

small emergence the second summer. All specimens of *S. substriatus* and three species of Cerambycidae emerged the second summer.

The only species present in significant numbers in the samples of western larch (Tables 1 and 2) were the wood borers *T. velutinum*, *S. substriatus*, *M. drummondi*, and the bark beetle *D. pseudotsugae*. The first two species lower the quality of the lumber by boring into the wood; the others may cause deterioration of the wood by introducing fungal organisms. The absence of *Monochamus* is consistent with the lack of records of this genus in western larch in the literature.

TABLE 2. Emergence of wood- and bark-feeding insects in 1928, and 1929 (brackets) from a western larch tree felled in May 1927 and stump, bole and limbs caged separately in May 1928, Trinity Valley, B.C.

Species	No. emergents ex.			Emergence range	
	Stump	Bole	Limbs	1928	1929
CERAMBYCIDAE					
<i>Anoplodera crassipes</i> Lec.	1	0	0	Jul 20	
<i>Phymatodes densipennis</i> Csy.	0	0(4)	0		May 28- Jun 9
<i>Phymatodes dimidiatus</i> (Kby.)	1	0	0	Jun 4	
<i>Pogonocherus pictus</i> Fall	0	1	1	Aug 21- 29	
<i>Rhagium lineatum</i> Oliv.	0(1)	0	1	May 11	Jun 26
<i>Spondylis upiformis</i> Mann.	1	0	0	May 20	
<i>Tetropium velutinum</i> Lec.	3	565(71)	149(8)	May 16- Aug 27	May 25 Sep 13
<i>Xylotrechus undulatus</i> (Say)	0	0(1)	0		Jul 30
MELANDRYIDAE					
<i>Scotochroa basalis</i> Lec.	0(1)	2	2(1)	Aug 18- 29	Jul 5
<i>Serropalpus substriatus</i> Hald.	0	0(61)	0(2)		Jun 4- Aug 4
BUPRESTIDAE					
<i>Melanophila drummondi</i> (Kby.)	2	97(4)	0	May 24- Aug 31	Jun 6- Jul 30
CURCULIONIDAE					
<i>Pissodes schwarzi</i> Hopk.	2	26	21	May 8- Aug 21	
SCOLYTIDAE					
<i>Dendroctonus pseudotsugae</i> Hopk.	127	482	1	May 8- Jul 20	
<i>Dryocoetes septentrionis</i> (Mann.)	2	0	0	Jun 13	
<i>Hylastes longicollis</i> Sw.	1	1	1	May 24- Jun 23	
<i>Hylastes nigrinus</i> (Mann.)	3	0	0	Jun 4- 10	
<i>Hylastes ruber</i> Sw.	3	1	0	Jun 18- 25	

THE WESTERN LARCH BORER, *TETROPIUM VELUTINUM* LECONTE, IN INTERIOR BRITISH COLUMBIA

D. A. Ross¹

ABSTRACT

In the interior of British Columbia, *Tetropium velutinum* LeConte is an important borer in the sapwood of western larch, *Larix occidentalis* Nuttall. Other authors have indicated that this borer was important only as a bark miner and killer of trees. Galleries penetrated to depths of 25 to 47 mm and ranged in total length from 28 to 69 mm. At Vernon oviposition was from early in May until the end of August. Limited observations showed that the first penetration of the sapwood by the larvae began about 6 weeks after oviposition.

INTRODUCTION

Webb (1911) briefly described the stages, damage to the bark, and status of *Tetropium velutinum* LeConte. Craighead (1923) noted that the species "...is of considerable economic importance, causing the death of *Tsuga heterophylla* and *Larix* throughout the Rocky Mountains and the Pacific Coast region." Kinghorn (1954) observed that it infested and killed numerous mature hemlock that had been weakened by an epidemic of hemlock loopers. He indicated that it was common in western Washington and Oregon, southern Vancouver Island, coastal mainland near Vancouver, and in the southern interior of British Columbia.

These authors noted that *T. velutinum* was important as a bark miner and killer of trees. Preliminary observations indicated that it might be more important as a wood borer than as a tree killer in the southern Interior (Ross 1966). In 1965-66, activity of the insect on and in logs was investigated to determine its significance as a wood borer, and to gain information for control procedures.

Sections of infested coniferous logs from Nelson and Kamloops forest districts were caged outdoors at Vernon. The adult *Tetropium* reared were placed, usually in pairs, in small cages containing a short bolt of freshly cut larch and some sugar

solution. Adult activity, egg incubation and larval feeding were observed.

OBSERVATIONS

HOSTS: In the interior of British Columbia this borer was most frequent in western larch, *Larix occidentalis* Nutt. logs or windfalls. In a few instances it was reared from *Pseudotsuga menziesii* (Mirb.) Franco, *Picea engelmanni* Parry, *Tsuga heterophylla* (Raf.) Sarg., *Pinus monticola* Dougl. and *P. contorta* Dougl. Its occurrence was confirmed as far north as Shuswap Lake.

ADULT ACTIVITY: The adult emergence period for material caged outdoors at Vernon was 18 May to 6 August in 1965, and to 2 May to 30 August, 1966. The major emergence period was between mid-May and mid-June. The average longevity for 17 pairs of adults was 11 days for males and 12 days for females. One male lived 13 days and one female 20 days. Adults mated readily the day of emergence when the temperature exceeded 19°C. Usually copulation was frequent for several days until the female began egg laying. Mating recurred the first day after oviposition. Both sexes occasionally mated with more than one adult.

Oviposition was observed in June between 0800 and 2000 hours P.D.S.T. at temperatures above 18°C., generally 2 to 4 days after emergence. The soft body of this insect allows it to squeeze under the loose bark and obtain deep penetration of the oviposi-

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tor between the bark scales. White eggs (about 1.2×0.4 mm) were deposited in loose clusters in a compressed state under bark scales and in the crevices of the tree bole.

The number of developed ovarioles in each ovary ranged from 31 to 36, indicating a high potential egg production during a short period. In the insectary, the maximum number of eggs deposited by one beetle was 208. The average number of eggs deposited by 10 of the most productive females was 130. The longest oviposition period for an individual was 11 days, and its daily egg production during that period was 10, 51, 2, 3, 10, 0, 3, 10, 3, 3, and 9 respectively.

INCUBATION: Incubation time in June ranged from 10 to 16 with an average of 13 days.

LARVAL ACTIVITY: The newly hatched larvae bored to the inner bark to feed. The extent of mining in the bark of a recently felled larch is shown (Fig. 1) for five larvae hatched on 28 June, 1966, and allowed to feed undisturbed for 41 days. Two larvae had begun to score the wood and the other three fed on the phloem and cambium. The first recorded penetration of the wood occurred just under 6 weeks following oviposition on 27 May.

The larval entrance hole into the wood was elliptical and ranged in size from 5.0×2.7 to 6.0×3.5 mm (Fig. 2). The wood was invariably scored along the entrance side of the hole for 2 to 5 mm. Penetration of the gallery into the wood extended to a depth of 25 to 47 mm. Most galleries were L-shaped (Fig. 3) with a gentle, simple curve in the entrance arm of the gallery. Length of 15 galleries varied from 28 to 69 mm; the volume varied from 0.42 to 1.28 cc (average 0.86 cc). Most larvae in caged bolts overwintered near the lower end of the well-plugged gallery.

PUPATION: Pupation occurred early in the spring mostly in galleries in the wood although a few pupated

under the bark. At 21°C . the pupal stage lasted from 7 to 9 days.

The adults emerged from the entrance holes that were frequently hidden by a flake of bark. The maximum number of holes recorded was $17/\text{ft}^2$, in a western larch log 200 mm in diameter.

Generally, this insect completes only one generation a year. However in 1965 a female oviposited on caged logs late in May and the brood produced five adults on 23 August two of which mated and produced eggs; several eggs hatched and the larvae wintered successfully.

In another instance eggs were deposited on 16 June and hatched 13 days later. The larvae fed for 47 days on the inner bark, then pupated in the bark on 16 August and an adult emerged 8 days later.

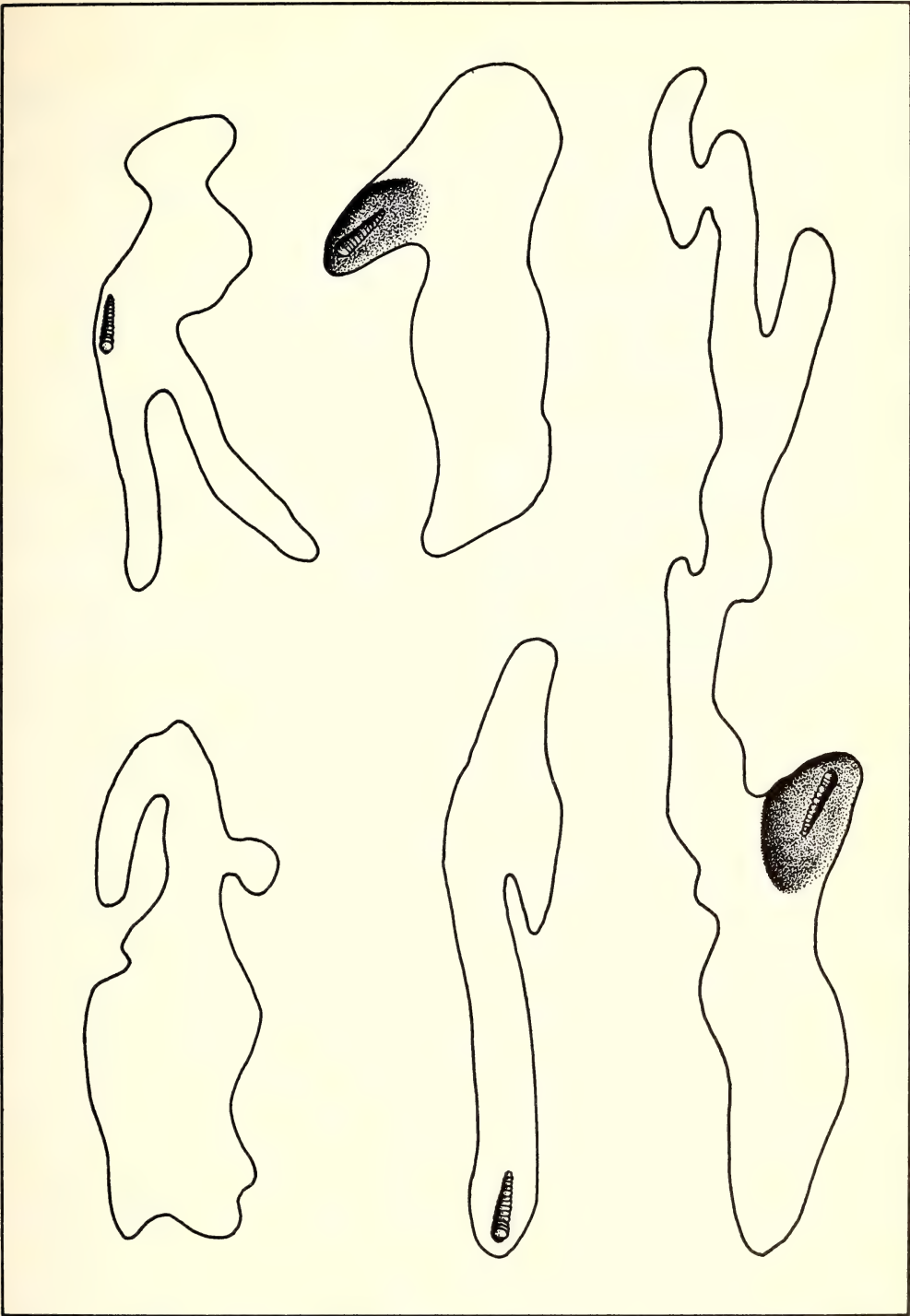
DISCUSSION

Other authors (Webb 1911; Craighead 1923; Kinghorn 1954; and Keen 1952) emphasized the importance of *T. velutinum* as a bark-mining tree killer, particularly of weakened western larch and hemlock. This phenomenon has not been observed in the interior of British Columbia; however, there are numerous records of the borer damaging the sapwood of western larch logs (Ross 1967). The L-shaped galleries extended into the wood to a depth of 25 to 47 mm, ranged in length from 28 to 69 mm, and had an average volume of 0.86 cc.

The life cycle usually takes 1 year, although a partial second generation may occur.

In 1966, at Vernon, oviposition began the first week in May and continued until the end of August. Therefore insecticides, which should persist throughout the summer, should be applied early in May.

There is evidence that during some years and under certain conditions larvae do not penetrate the sapwood until at least 6 weeks after oviposition. Although the duration



Figs. 1 - 3 *Tetropium velutinum* Lec.

1. Galleries in phloem made by five larvae left to feed undisturbed for 41 days.
Stippled area is scored wood.



2. Larval entrance holes in wood of *Larix occidentalis*.

3. Lead castings of galleries in wood (Geistlinger and Taylor 1962).

of this bark-mining stage must be determined for different conditions, it may be assumed that damage can be prevented if infested logs are processed or peeled before the end of June of the year of infestation. In situations where cool weather delays development, damage to the wood

may not begin until later. As for many other wood borers, damage can be avoided by prompt utilization of felled trees.

Acknowledgments

The writer is indebted to J. M. Kinghorn for suggestions for improving the manuscript.

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THE MARSH CRANE FLY, *TIPULA PALUDOSA* Mg., A NEW PEST IN BRITISH COLUMBIA (DIPTERA: TIPULIDAE)

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ABSTRACT

Tipula paludosa Meigen was firmly established in the Vancouver area by 1965, starting in the eastern outskirts of the city. It was taken at Blaine, Wash., in 1966. By 1967 the pest had spread to the Chilliwack area. Populations of 110/ft² were measured in 1966 and local observations were recorded of damage, oviposition, feeding, growth, and emergence. A review is included of European literature on populations, life history, weather relations, and biological, chemical and cultural controls, with some speculation on the future.

INTRODUCTION

In the past three years the leatherjacket or larva of the European marsh crane fly, *Tipula paludosa* Mg., has become a serious problem in lawns and pastures in the lower Fraser Valley. Identification was by J. R. Vockeroth, Entomology Research Institute, Ottawa. This is the most common and damaging crane fly in northwestern Europe. The leatherjackets were first found in 1965 causing severe damage to lawns in the eastern outskirts of Vancouver. In 1966 they were considerably more widespread and in pastures on several small farms in this area there was virtually no growth until the middle of May. In the fall adult *T. paludosa* were trapped at Blaine, Washington, 25 miles southeast of Vancouver (U.S.D.A. Cooperative Economic Insect Rpt. 16: 946, 949, 956. 1966). In 1967 heavy infestations of leatherjackets and the resulting damage occurred on large dairy farms near Pitt Meadows, 20 miles east of Vancouver, and in lawns at Yarrow, 30 miles farther east.

The first North American record of this pest was in 1955 on Cape Breton Island (Fox, 1957) where lawns and flowers were attacked. The infestation there was thought to have originated in soil used for ships ballast and dumped ashore. In Newfoundland Morris (1960) reported

damage in 1959 to cabbage transplants and turnip seedlings. The origin of the present outbreak is a matter for speculation; a good guess would be the balled roots of ornamentals imported from Europe.

LOCAL OBSERVATIONS

Most of the damage in British Columbia has been to lawns and pastures but flowers, strawberries and vegetable crops in backyard gardens have also been attacked. These infestations have been easily controlled with DDT or aldrin, but the rapid spread of this pest to pasture has presented a much more serious problem. The lower Fraser Valley is primarily a dairying region, and there is great danger of insecticide residues occurring in meat and milk fats if these and similar persistent insecticides are applied to forage or fodder.

In 1966 preliminary studies were carried out in a heavy infestation on a 10-acre farm. In April and May the larval population was measured in 84 samples, each of ¼ sq ft, on about 4 acres. Gasoline sprayed on the turf brought nearly all the larvae to the surface where they were readily counted. The top 1-inch of sod was examined for the remainder that did not emerge. The population per sq ft averaged 109.6 (range 24-232), or close to 5 million per acre.

Rototilling and disking reduced the population by about two-thirds but the reduction was not enough to allow a new seeding to survive. When

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oats and grass were planted on April 26 nothing grew, not even volunteer grass or weeds. The larvae matured and stopped feeding about the middle of May. Oats and grass planted on May 20 produced a good crop.

On warm, cloudy days in March and April, the larvae were observed on the surface feeding on the crowns and blades of grass. On bright days they remained in the sod but fed on the surface at night. The larvae were generally found in the top 1-inch of sod, but after about the middle of May they moved downward and many were found as deep as 3 inches below the surface.

Emergence and adult populations were studied by placing six 1-sq-ft cages in a pasture and taking counts twice weekly. The adults started emerging during the first week of August, peaked about September 1, and the last one was collected on September 30. The average number of adults per sq ft was 98 (range 75-112) consisting of 55 males, 43 females.

The egg capacity was observed by Coulson's (1962) method of removing the head from newly-emerged and mated females from the field and floating them on water which induces them to oviposit. The eggs remaining in their abdomens were also counted. The average number of eggs based on 10 females was 281 (range 243-338). This is lower than the average of 360 reported by Coulson (1962) in the north of England but close to Barnes' (1937) figure of 272 in the south.

No parasites have emerged from many hundreds of larvae reared in the laboratory, nor have larvae been observed killed by virus. The only predators seen were spiders and possibly the numerous European starlings, *Sturnus vulgaris*, which appear to feed on larvae and adults. Average survival from the late larval stages to adults was high when 98 adults were obtained from an average of 110 larvae per sq ft. This suggests that there are at present low levels of cannibalism, predation, parasitism and dis-

ease in this infestation.

POPULATIONS

It is clear that numbers of the pest were in a runaway phase during 1966. Maercks (1939) in northern Germany, considered that 5 per sq ft would cause serious injury in arable land, and 10 per sq ft serious injury in grass land. Cohen & Steer (1946) considered 20 per sq ft to be a heavy infestation. The population level is likely to decline as existing and imported biological controls assert themselves.

LIFE HISTORY

Several experienced investigators have studied *T. paludosa*, and their accounts are well in agreement with one another. The species appears to be mostly univoltine but some authors state without offering evidence that there may be a partial or complete 2nd generation.

Egg. The eggs are black and shiny, 1.1 x 0.4 mm, are laid at night in August and September, and have very high moisture requirements at first. They will collapse within 2 to 4 minutes in less than 100% relative humidity (Laughlin, 1958). The minimum mortality occurs in upland soil holding twice its dry weight of water (Maercks, 1939). They are laid on or very close to the surface, 68% within 1 cm of it according to Coulson (1962). Rennie (1916) considered that not all the eggs were mature on the emergence of the female, and that some were retained to produce a 2nd batch. Most later workers think that remaining unlaid eggs are simply a residue. The eggs develop without diapause (Sellke, 1936).

Larva. The larvae hatch in 11 to 15 days (Rennie, 1917; Barnes, 1937). They feed from the first day, starting at approximately 2.7 mm long, with 13 segments, growing to 4 or 5 mm in 12 to 13 days (Rennie, 1917). Mortality is high for the first 20 to 30 days (Laughlin, 1958).

The first two instars of three are passed in about 14 days in central England (Barnes, 1937). In six weeks

they are about 6 mm long. The winter is spent in the 3rd instar (Fig. 1), which is without diapause and lasts roughly 25 weeks (Sellke, 1937; Coulson, 1962). Growth is rapid in spring when most of the damage occurs (Rennie, 1917). Minimum larval mortality occurs in upland soil holding three times its dry weight of water (Maercks, 1939). Young larvae appear to prefer green leaves to roots and grow most rapidly with least loss on white clover. They also rear easily on lettuce, wheat and rye, but may not complete development on oats (Maercks, 1939). Normally, but not invariably, they surface to feed, during darkness (Sellke, 1937).

Pupa. The larvae stop feeding in mid-May for two or three weeks before pupating (Fig. 2). When the adult is ready to emerge the pupa works its way to the surface where the empty pupal case is left by the emerging adult, characteristically protruding 2.5 cm from the ground. These are easily sexed, and a ratio of 1.72 males to 1 female was established by Coulson (1962). Cannibalism may be a reducing factor in the early stages of pupation.

Adult. The adults emerge soon after sunset in August and September, mate immediately (Fig. 3), lay 75% of their eggs before daylight (Sellke, 1937; Barnes, 1937; Coulson,

1962) and have finished laying within 32 hrs of emerging (Coulson, 1962). They fly very little before laying, but may leave 5 or 6 eggs in one spot, then move a short distance (Rennie, 1917). Males live about 7 days, females from 4 to 5 days (Barnes, 1937). In a 4-year study at Rothamsted, 57% of 3,400 adult crane-flies were of this species (Robertson, 1939).

WEATHER RELATIONS

Maercks (1941) concludes that this pest is favored by mild winters, cool summers, and rainfall averaging at least 24 inches per year. Mean monthly values for temperature, precipitation and numbers of days with rainfall are shown by months in Table 1, based on 30-year averages at the Vancouver International Airport. Values for agricultural areas of the lower Fraser Valley differ only slightly. It thus appears that the maritime climate of the wet, coastal belt of British Columbia is practically ideal for this pest.

The present outbreak has been favored by recent weather patterns. In the 5 years, 1962-1966, mean monthly temperatures in winter and summer were above normal as follows:

Nov.	Dec.	Jan.	Feb.	May
4/5	2/5	3/5	5/5	0/5
	June	July	Aug.	
	0/5	0/5	0/5	

The conclusion is that the pest has had five years of ideal conditions in which to become well established.

Damage may be expected following a wet September, especially if the following winter is mild (Maercks, 1941). A cold spring contributes to damage, because the danger period in annual crops is from the time of sowing to the growth of adventitious roots (Rennie, 1917). Robertson (1939) noticed that twice as many adults were taken at light traps on moonless nights as on moonlit ones, and three times as many on cloudy as on clear nights. Most of the trapped adults were males.

TABLE 1—Mean monthly temperatures, precipitation, and days with rain, based on 30 years of records, Vancouver International Airport.

Month	Mean mo. temp., °F	Mean mo. precipitation, with rain inches	Mean days
Jan.	37.2	5.52	19
Feb.	39.4	4.74	16
March	43.2	3.76	16
April	48.3	2.30	13
May	55.0	1.92	10
June	60.4	1.84	9
July	63.8	1.04	6
Aug.	63.6	1.37	8
Sept.	57.8	2.13	9
Oct.	50.3	4.62	15
Nov.	43.1	5.44	18
Dec.	39.6	6.44	20
Total		41.12	159



BIOLOGICAL CONTROLS

T. paludosa is not effectively controlled naturally in northwest Europe. The most effective insect parasite appears to be *Siphona geniculata* De Geer, a small Tachinid that lays up to 9 eggs on the stigmatic crown of the leatherjacket. The larvae enter the main tracheal trunks and bore into the hemocoele but retain a respiratory connection with a chitinous sheath-like structure. There are two generations per year and the parasite overwinters in the host, but the level of parasitism is never high. One record shows 34% to have been affected but the average is much lower, from 6 to 17% (Rennie & Sutherland, 1920). The Vancouver Station is attempting to establish *S. geniculata* supplied by the Institute for Biological Control, Belleville, Ont.

Two virus diseases of leatherjackets have been recorded and plans to use these are under way at Vancouver. However, they do not appear to be highly contagious, although fatal. *Empusa* (= *Entomophthora*) has been recorded as infesting populations in Germany (Müller-Kögler, 1957), and a fungal infection of the tracheae is known (Coulson, 1962). Two species of saprozoic and parasitic nematodes have been recorded in Denmark (Bovien, 1937). Cannibalism is a mortality factor in laboratory rearing, but its effect in the field is difficult to assess and probably small. George (1966) concludes that there is little evidence for effective diseases.

Predation on larvae, especially by European starlings and native moles, *Scapanus* spp., should be studied. Predation on adults is probably not effective, since any adult taken is likely already to have expended most of its quota of eggs.

CHEMICAL CONTROLS

The problem is twofold: how to treat land without creating a residue

hazard, and how to live with the pest at the same time keeping down costs. Fortunately the larvae are easily killed and will accept baits readily. They have thin integument, permeable enough for gaseous exchange, lacking an epicuticular layer (Ghilarov & Semenova, 1957). Moreover, 1st and 2nd instar larvae remain close to the surface, and have been killed even by mineral fertilizer (Sellke, 1937).

CULTURAL CONTROLS

Leatherjackets may be reduced by cultivation, since they do not go deep into the soil, but when the numbers are very large the reduction may not be effective. However, *T. paludosa* is adaptable enough to survive and reproduce without the presence of growing plants, by eating decaying rootlets after the manner of wireworms (Rennie, 1917). Maercks (1941) advocates good drainage of land and short grass during egg-laying in August and September. The deleterious effect on the eggs and young larvae of dry weather, may sometimes be offset by the practice of irrigating pastures with sprinklers.

FUTURE PROSPECTS

Review of the extensive European literature indicates that *T. paludosa* is likely to become a constant and possibly a major pest in areas of high rainfall. There are dozens of records of damage by this species in northwestern Europe in research papers and annual reports from Denmark, U.K., Germany, Sweden and Holland. It probably will establish itself in northwestern Washington, but its southern and eastern spread may be restricted by cold winters and by its high moisture requirements. Population crashes in northern England in 1955 and 1959 were shown experimentally by Milne *et al.* (1965) to result from very dry conditions at critical periods.

Fig. 1—Mature 3rd-instar larvae of *T. paludosa*.

Fig. 2—Pupa of *T. paludosa*.

Fig. 3—Marsh crane flies, *Tipula paludosa* in copula.

They predicted that increases may be expected if rainfall in August and September is normal or greater than normal, but when rainfall at this time drops below 50% of normal, sharp declines will certainly occur.

Nevertheless there is likely always to be a residue in low-lying land and in ditch-banks.

It appears unlikely that resistance to chemical pesticides will develop within 15 to 20 years.

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NEW RECORDS AND DISCUSSION OF PREDATORS OF THE PEAR PSYLLA, *PSYLLA* *PYRICOLA* FORSTER, IN BRITISH COLUMBIA¹

BY R. D. McMULLEN and C. JONG

ABSTRACT

The following species are presented as new records of insect predators of the pear psylla, *Psylla pyricola* Förster, in British Columbia:

Anthocoris nemoralis (F.), *Campylomma verbasci* (Meyer), *Deraeocoris brevis piceatus* Knight, *D. fasciolus* Knight, *Diaphnocoris provancheri* (Burque), *Adalia frigida* Schn., *Calvia duodecemmaculata* Gebl., *Coccinella transversoguttata* Fald., *Hippodamia quinquesignata* Kirby, *Platypalpus* sp. near *pluto* Mel., *Hemerobius pacificus* Banks. The biologies of some of the most common predators of the pear psylla are briefly discussed.

INTRODUCTION

The role of predaceous insects in the natural control of *Psylla pyricola* Förster has been documented and discussed by several workers. Until Madsen (1961) presented observations on predation of *P. pyricola* by *Anthocoris melanocerus* Reuter in British Columbia and speculated on its importance in the natural control of this species there were very few published records of predators of *P. pyricola* in North America. Previously, Slingerland (1896) observed predation by *Chrysopa oculata* Say and *Adalia bipunctata* (L.) in New York. More recently *Chrysopa carnea* Fitch, *C. ploribunda* Fitch, *Hemerobius angustus* (Banks), *Anthocoris antevolens* White and *Orius* sp. were recorded as predators in studies evaluating the natural control of *P. pyricola* in California by Madsen, Westgard and Sisson (1963) and Nickel, Shimizu and Wong (1965). In British Columbia, Wilde (1962) and Wilde and Watson (1963) reported the following species as predators of *P. pyricola*: *C. carnea*, *C. oculata*, *A. antevolens*, *A. melanocerus*, *Orius tristicolor* White, *Hippodamia convergens* Guérin-Meneville, *Magilla fuscilabris* Mulsant and the larva of a syrphid fly, *Sphaerophoria* sp.

Additional records of species predaceous on *P. pyricola* are presented below. The biologies of these and some

of the previously known predators are discussed.

METHODS

Most of the records of predation were obtained from two pear orchards. One, located at the Research Station, Summerland, has a grass sod cover crop and has received all the standard horticultural practices except for the application of pesticides for the past 18 years. The other, located at Penticton, has a weedy cover crop and has been maintained as a commercial orchard. During the past three years portions of the orchard have been treated with various insecticides and parts left untreated for experiments on the integrated control of pests of pear.

The presence and relative abundance of active stages of predators in pear trees were determined by the limb-jarring method (Lord, 1949). The orchards were sampled in this manner at weekly or biweekly intervals from early March to mid-October. Observations on acts of predation were usually made first in the orchard, often with the aid of a hand lens, and then confirmed in the laboratory. Nymphs and adults of suspected predators were caged with various stages of *P. pyricola* and observed through a low-power microscope.

During the growing season the eggs of predators and preferred oviposition sites were identified by observing oviposition in the orchard.

¹ Contribution No. 216, Research Station, Research Branch, Canada Department of Agriculture, Summerland, British Columbia.

Also eggs suspected of being those of predators were reared in the laboratory to stages that permitted identification.

Information on overwintering habits were obtained by several methods. Corrugated cardboard bands were placed on trees in the early autumn to serve as artificial hibernation sites. These were examined during the winter. Cracks and crevices in the bark on tree trunks and limbs were also examined. During the winter, orchard trash, sod and top soil were processed through Berlese type funnels to aid in the assessment of preferred overwintering sites. For species that overwinter in the egg stage, branches and twigs containing suspected eggs of predaceous species were placed in water filled jars in a greenhouse during the late winter. The nymphs that hatched from the eggs were reared to an identifiable stage.

NEW RECORDS OF PREDATORS OF *PSYLLA PYRICOLA* FORSTER IN BRITISH COLUMBIA

The following species represent new predator records obtained during the course of this study:

Anthocoris nemoralis (F.) (Heteroptera:Anthocoridae)

Campylomma verbasci (Meyer) (Heteroptera:Miridae)

Deraeocoris brevis piceatus Knight (Heteroptera:Miridae)

Deraeocoris fasciolus Knight (Heteroptera:Miridae)

Diaphnocoris provancheri (Burque) (Heteroptera:Miridae)

Adalia frigida Schn. (Coleoptera:Coccinellidae)

Calvia duodecemmaculata Gebl. (Coleoptera:Coccinellidae)

Coccinella transversoguttata Fald. (Coleoptera:Coccinellidae)

Hippodamia quinquesignata Kirby (Coleoptera:Coccinellidae)

Platypalpus sp. near *pluto* Mel. (Diptera:Empididae)

Hemerobius pacificus Banks (Neuroptera:Hemerobiidae)

DISCUSSION

Chrysopidae. Very little information has been published on the biologies of *Chrysopa* spp. in British Columbia. Current investigations indicate that one or more species are important predators of *P. pyricola*. Adults of *C. carnea* and *C. oculata* are common in pear orchards. By direct observation in pear orchards and laboratory rearing, the larvae of both species are known to prey on eggs and nymphs of *P. pyricola*. However, information on the relative abundance of the two species on pear trees is lacking. In the light of a statement by Putman (1932) that *C. oculata* is restricted almost entirely to low vegetation in Ontario peach orchards, the value of this species in an arboreal habitat is questionable. In pear orchard cover crops, *Chrysopa* spp. larvae are abundant on weeds infested with aphids and other arthropods in cover crops. But again, the species concerned and their relative abundance are not known.

Chrysopa spp. larvae are present in pear orchards and prey on eggs and nymphs of *P. pyricola* from early May through October. They are most abundant in July and August. Additional records of prey species on pear trees include all stages of the European red mite, *Panonychus ulmi* (Koch), and the two-spotted spider mite, *Tetranychus telarius* (L.), larvae of the fruit-tree leaf roller *Archips argyrospilus* (Walker), the apple aphid *Aphis pomi* DeGeer and nymphs of unidentified leafhoppers (Cicadellidae).

Hemerobiidae. Of the brown lacewings, *Hemerobius pacificus* Banks is the only species that has been verified as preying on eggs and nymphs of *P. pyricola* in British Columbia, but other species may also be involved. In the pear orchards studied, brown lacewings were only about one-tenth as abundant as were green lacewings. In contrast, Nickel, Shimizu and Wong (1965) stated that *H. angustus* was more common than *C. carnea* in

pear orchards near San Jose, California.

Anthocoridae. The distribution, life histories and habits of several species of Anthocoridae in British Columbia, including *Anthocoris antevolens*, *A. melanocerus* and *Orius tristicolor* have been discussed by Anderson (1962a). *A. melanocerus* and *A. antevolens* are two of the most abundant predators of *P. pyricola* in unsprayed pear orchards. Both species overwinter as adults. Nymphs are frequently found in hibernation but they are killed by winter temperatures. In pear orchards, adults are most commonly found during the winter beneath bark scales and in cracks on the lower scaffold limbs and trunks of trees. Accumulations of dry orchard trash on the ground are also favored as overwintering sites. Adults of both species exhibit aggregational behavior during hibernation and both species occur in the same aggregations.

Dispersal from overwintering sites in early spring is gradual and usually begins when daily maximum temperatures exceed 50°F. After dispersal the adults search for sources of prey and then remain to feed and oviposit where food sources are adequate. In pear orchards, eggs laid by overwintered *P. pyricola* and overwintered eggs of *P. ulmi* appear to be the main prey and attraction.

The sex ratio, males to females, of both *A. antevolens* and *A. melanocerus* is approximately 1:10 in overwintered populations. The females are fertilized in the fall and additional mating in the spring is not required. The sex ratios of summer generations is approximately 1:1. Oviposition starts before pear buds are opened. At this time, eggs are inserted into bud scales. Later in the season, eggs are laid into any soft green tissue, most frequently in the lamina, veins and petioles of leaves. The eggs are inserted into the tissue, just beneath and parallel to the surface with only the operculum exposed.

Anderson (1962a) gave the time required to complete one generation under laboratory conditions for *A. antevolens* as five to six weeks and for *A. melanocerus* as four to five weeks. Field observations during 1965 and 1966 indicated that at Penticton and Summerland there were four generations per year of each species. Females maturing after the first week of September do not reproduce but enter a state of reproductive diapause in preparation for overwintering.

Anthocoris spp. must be considered as among the most important natural control agents of *P. pyricola*. They are abundant and their seasonal distribution is more closely synchronized with that of *P. pyricola* than other predators. They are the only abundant species which prey on *P. pyricola* in the latter half of March and the first half of April.

Other records of predation by *Anthocoris* spp. on pear trees include all stages of *P. ulmi* and *T. telarius*, eggs of the codling moth, *Carpocapsa pomonella* (L.), small larvae of *A. argyrosipilus* (Walker) and nymphs of unidentified leafhoppers (Cicadellidae). Both species also feed on a variety of small arthropods and reproduce on weeds in pear orchard cover crops.

Anthocoris nemoralis is not a native of British Columbia but was introduced at Summerland from Europe as a predator of *P. pyricola* by the Canada Department of Agriculture in co-operation with the Commonwealth Institute of Biological Control. In June, 1963, 50 were released in an experimental pear orchard. By August, 1966, the species was very abundant at the release site and had dispersed to other orchards at least 1.5 miles distant.

Psyllids are preferred prey for *A. nemoralis* (Anderson, 1962b). In England there are only two generations per year. This species differs from most other *Anthocoris* spp. in that the sex ratio of males to females in the overwintering generation is ap-

proximately 1:1 (Anderson, 1962c). The biology of this species in its new environment has not yet been studied. Since *A. nemoralis* probably occupies a niche very similar to that of *A. melanocerus* and *A. antevolens*, observations on competition between these species will be of interest.

Orius tristicolor is a minor predator of *P. pyricola*. In pear orchards it is more abundant near the ground on cover crop plants than in the canopy of pear trees. Adults have been observed feeding on *P. pyricola* eggs and small nymphs. Nymphs of *O. tristicolor* are rare on pear foliage.

Miridae. The mullein plant bug, *Campylomma verbasci*, is an important predator of *P. pyricola* during the month of May. The species overwinters in the egg stage. The eggs are inserted into the bark of current season twig growth during the latter half of September to mid-October. The overwintered eggs hatch in early May just before pears bloom. There are three or possibly four generations per year. Most of the adults of the first generation leave pear orchards to reproduce on a variety of wild and cultivated herbaceous plant species. Some remain in pear orchards but the later generations are never so numerous as the first generation. In the fall, adults of the last generation return from herbaceous hosts to oviposit overwintering eggs on pear and apple trees.

C. verbasci plays an important role in the natural control of *P. pyricola* because it occurs in large numbers on pears when most other predaceous species are relatively scarce. Besides feeding on eggs and nymphs of *P. pyricola*, prey records for *C. verbasci* on pear include all stages of *P. ulmi* and *T. telarius*.

In addition to being predaceous *C. verbasci* is phytophagous. Reports of injury to apple are well authenticated (Ross and Caesar, 1920; Pickett, 1939 and Leonard, 1965). During the course of the present observations no adverse effects were noted on pear

fruits, even when relatively large numbers (30-35 per cluster) of nymphs were present and feeding in clusters of immature fruit during May. *C. verbasci* is recorded as a vector of the fire blight organism, *Bacillus amylovorus* (Burr) Trev. by Stewart and Leonard (1915). This could negate its value as a predator.

As a predator of *P. pyricola*, *Deraeocoris brevis piceatus* ranks second in importance to *Anthocoris* spp. This species is most abundant during mid-summer and early fall. It overwinters as an adult, most commonly in heavy dry trash in and around orchards and also in crevices in the bark of trees. The sex ratio of overwintered adults is approximately 1:1 and mating in the spring is required for the production of fertile eggs. Overwintered adults become active in early April when they seek out and feed on their prey. Oviposition habits are similar to those described for *Anthocoris* spp. The earliest hatched nymphs of the first generation appear during the first week of May. Oviposition by overwintered females is extended over a period of several weeks so that very young nymphs of the first generation are present when the earliest hatched individuals have completed development. There are at least four generations per year. Reproduction ceases in mid-September and all adults maturing after this time undergo a reproductive diapause. Feeding by adults continues until cold weather in October or November forces the adults into protective hibernation sites. Infrequently, nymphs have been observed in artificial hibernation sites but none have overwintered successfully.

Records of prey of *D. brevis piceatus* on pear include eggs and nymphs of *P. pyricola*, all stages of *P. ulmi* and *T. telarius*, small larvae of *A. argyropilus*, eggs of *C. pomonella*, nymphs and adults of the apple grain aphid, *Rhopalosiphum fitchii* (Sanderson), and *A. pomi*, and nymphs of unidentified leafhoppers (Cicadellidae).

In pear orchards, eggs and nymphs of *P. pyricola* appear to be the chief prey of this species. In laboratory studies, eggs rather than nymphs of *P. pyricola* were preferred as prey.

In the laboratory as well as in orchards nymphs and adults were occasionally observed feeding on leaves and immature fruit. No apparent injury occurred. The significance of this partial phytophagous habit to the nutrition and development of this species, as well as the other species of Miridae discussed, has not been determined. A partial phytophagous habit may be of importance in sustaining populations of predaceous insects when arthropod prey are absent or at low densities (Collyer, 1953).

Deraeocoris fasciolus is a common predator of *P. pyricola* that is most abundant in mid-summer to early fall. Little is known about the biology of this species in British Columbia. It overwinters in the egg stage. The eggs are inserted deep into the bark of rough twigs and fruit spurs of pear trees. Newly hatched nymphs first appear about mid-May. There are two generations per year. Prey records include eggs and nymphs of *P. pyricola* and all stages of *P. ulmi*.

Diaphnocoris provancheri overwinters in the egg stage. There are two generations per year. The nymphs of the first generation first appear in pear orchards during the third week

of May. The adults of the second generation mature and oviposit overwintering eggs in the bark of fruit spurs and one and two-year old twigs during the second and third weeks of September. Records of prey on pear includes eggs and nymphs of *P. pyricola* and all stages of *P. ulmi* and *T. telarius*. Both adults and nymphs are phytophagous as well as predaceous but plant feeding is restricted to foliage. No discernable injury to pear trees has been observed.

Coccinellidae. As individual species and as a group the Coccinellidae rank as minor predators of *P. pyricola*. At no time during this investigation have the numbers of Coccinellidae in predator samples exceeded one per cent of the total predaceous fauna.

Empididae. Adults of *Platypalpus* sp. near *pluto*, a dance fly, prey on adult *P. pyricola*. This species is frequently numerous in unsprayed pear orchards. The flies have been observed seizing adult *P. pyricola* resting on foliage and in flight. No attempt has been made to assess the importance of predation by this species toward natural control of *P. pyricola*. However, it is the only species that has been observed to prey consistently on the adult stage of *P. pyricola*. Clausen (1940) mentions that the larvae of Empididae are either predaceous or scavengers in moist soil or decaying wood habitats.

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CONE INSECTS OF GRAND FIR, *ABIES GRANDIS* (DOUGLAS) LINDLEY, IN BRITISH COLUMBIA

A. F. HEDLIN¹

ABSTRACT

Insects cause considerable seed loss in cones of grand fir, *Abies grandis* (Doug.) Lindl. on Vancouver Island. Three species of midge, a scale feeder, a gall former, and a seed-feeding midge; two species of seed chalcid, *Megastigmus pinus* Parf. and *M. rafni* Hoff.; and a cone maggot, *Earomyia abietum* McAlpine, were responsible for most of the damage. Coneworms were not important.

INTRODUCTION

Insects that destroy seed of grand fir, *Abies grandis* (Douglas) Lindley, have received little attention. Keen (1958) reported that insects, mainly chalcids and midges, destroyed 10 to 25% of the seed at Ashland, Oregon.

Information on insect species, and the type and extent of their damage was gathered on Vancouver Island in the summer of 1963. Cones collected weekly from 14 June to 19 August near Cowichan Bay contained midges, seed chalcids, cone maggots, and a few coneworms.

Grand fir flowers in spring and the cones mature by early September. Cones are erect, varying in length from 2.0 to 4.5 inches at maturity. In autumn they disintegrate.

LIFE HISTORY AND HABITS

Midges

Three species of midges, consistently present in cones, were distin-

guished by morphological characteristics and by their location in the cone (Fig. 1). Larvae of the scale midge feed on the inner surface of the cone scales, and have anal hooks which are absent in the cecidogenous midge and the seed midge. Morphological differences of the sternal spatulas of full-grown third instar larvae are compared in Fig. 2.

SCALE MIDGE. This is probably the insect which Keen (1958) refers to as the cone resin midge. The full-grown larva is orange and lives freely on the inner surface of the cone scale, often between the seed wing and scale, causing darkening of the scale at the feeding site. Larvae usually occur singly, but may be in clusters. Larvae are present throughout the summer; they averaged 28 per cone in eight cones dissected during June and July. In autumn the larvae drop to the ground to overwinter. The larvae do not affect the seeds directly so their damage is apparently light

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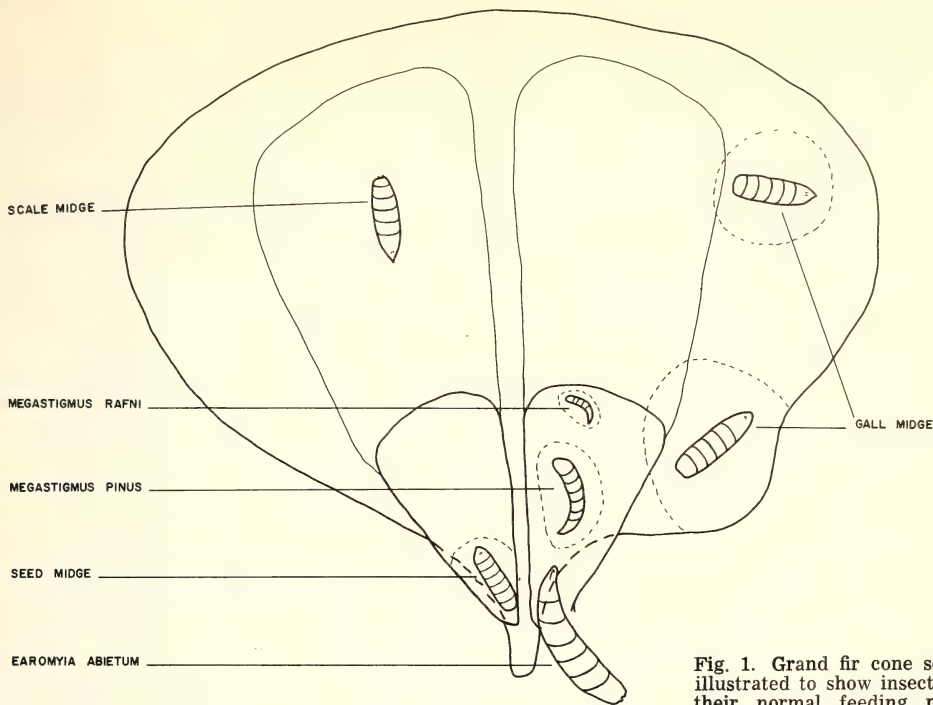


Fig. 1

Fig. 1. Grand fir cone scale illustrated to show insects in their normal feeding positions.
Fig. 2. Sternal spatulas of grand fir cone midges; (a) scale midge, (b) cecidogenous (gall) midge, (c) seed midge.

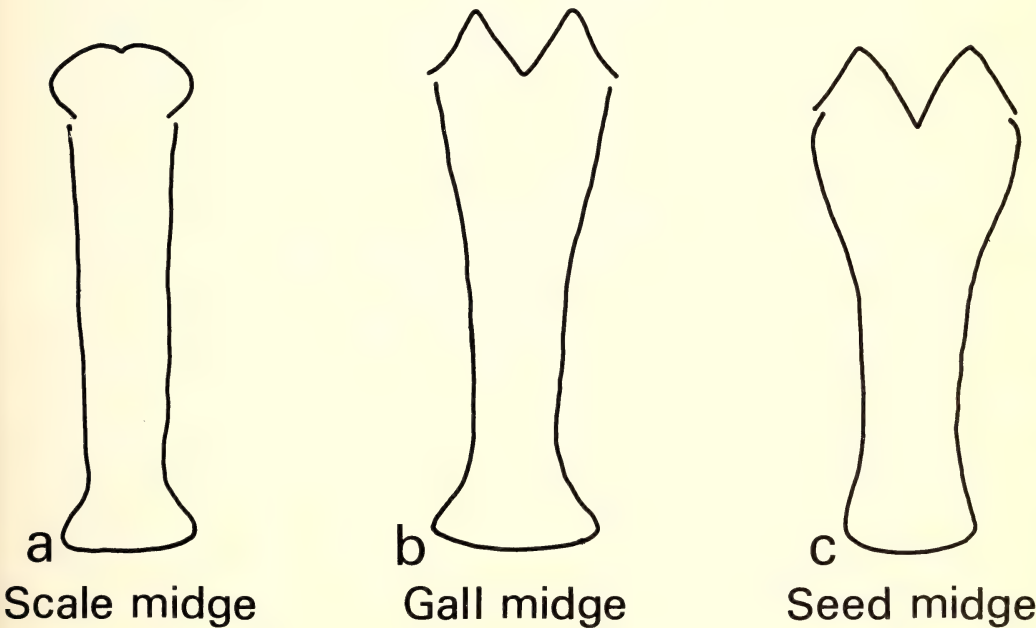


Fig. 2

in spite of large numbers.

CECIDOGENOUS MIDGE. The larva forms a gall in the cone scale, usually adjacent to the seed (Fig. 3), but is rarely found inside a seed. There is usually only one larva but two, separated by a thin wall, may be present in a single gall. The larva remains in the gall throughout the summer and drops with the cone scale in autumn to overwinter in the litter; pupation and emergence occur the following spring.

Seed loss results from fusion of the seed and cone scale. The eight cones examined were infested by an average of 13 larvae.

SEED MIDGE. Keen (1958) combines this species and the cecidogenous midge under the name "fir-seed gall midge", but the two are distinct species. The cecidogenous midge always forms a gall and rarely occurs inside the seed, whereas the seed midge does not form a gall and the larva occurs singly within a seed, near the micropylar end (Fig. 4).

Larvae occur in seeds throughout the summer and drop with the seeds when the cones mature. They overwinter in seeds on the ground, and pupate and emerge the following spring.

Nearly all infested seeds were aborted. Although the larvae occur singly in seeds, one was found with a seed chalcid larva and another with a cecidogenous midge larva. The eight cones were infested by an average of 6.6 seed midge larvae.

SEED CHALCIDS

Two species of *Megastigmus* are common in seeds of grand fir. Typically, the egg, larval, and pupal stages in this genus all occur within a seed.

Megastigmus pinus Parfitt. Adults are black with orange and yellow markings.

They emerged from seeds from 21 May to 11 June in 1958 (Hedlin, unpublished data), and during the last half of May in 1963. Thirty adult females and four males lived a maximum of 12 days and six days respec-

tively, when caged outdoors without food.

Although adults were observed ovipositing, eggs were not isolated. Larvae were observed first on 10 June, 1963, near the micropylar end of the seed which indicated that eggs were deposited in this region. They moved gradually throughout the length of the seed (Fig. 5) and when fully developed, almost filled it. When two are present in the same seed only one survives. Full-grown larvae are very active when disturbed and are easily distinguished from the sluggish *M. rafni*.

Eight cones contained an average of 25 larvae.

Megastigmus rafni Hoffmeyer. Adults are brownish yellow, with dark markings, similar in appearance to *M. spermotrophus* Wachtl which infests Douglas-fir seed.

Adults emerged from 9 to 19 June in 1958 (Hedlin, unpublished data) and during the first half of June in 1963, somewhere later than *M. pinus*.

The first larvae to be observed, on 2 July, were at the distal end of the seed feeding towards the micropylar end. The full grown larva reacts sluggishly when disturbed. When larvae of *M. rafni* and *M. pinus* occur within the same seed, the former is destroyed.

Eight cones contained an average of 3.4 larvae. The numbers of *M. rafni* are reduced by competition from *M. pinus*.

FIR CONE MAGGOTS

Earomyia abietum was the only species observed. Keen (1958) refers to this and other species of this group as "fir seed maggot". The name implies a seed feeder, and although the larva feeds on seeds it is also highly predacious, particularly in later instars. Thus I prefer the name "fir cone maggot" which does not imply specific feeding habits.

The opaque, white, sausage-shaped eggs are laid, usually singly, on the inner surface of the cone scale in May. Hatching occurs in late May and

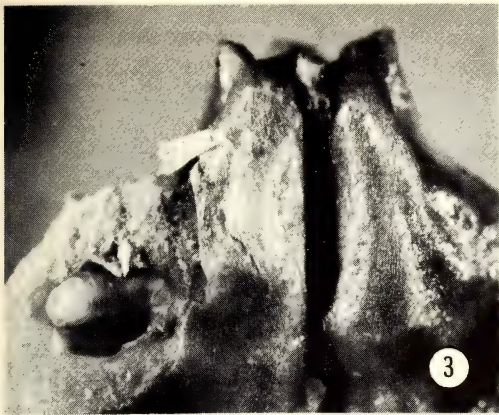


Fig. 3. Cecidogenous (gall) midge. Top of gall removed to expose larva.
Fig. 4. Seed midge. Seed opened to expose larva.
Fig. 5. *Megastigmus pinus*. Seeds sliced open to expose larvae in feeding tunnels.
Fig. 6. Entry holes of *E. abietum* in grand fir seeds.
Fig. 7. Puparia of *Earomyia abietum*.

TABLE I
Numbers of insects and numbers of seeds destroyed in grand fir cones,
Cowichan Bay, B.C., 1963 (Basis eight cones).

Insect	No. insects per cone	Seed loss	
		direct	indirect
Scale midge	28.0		7.0
Gall midge	13.0		13.0
Seed midge	6.6	6.6	
<i>Megastigmus pinus</i>	25.0	25.0	
<i>Megastigmus rafni</i>	3.4	3.4	
<i>Earomyia abietum</i>	1.3		5.0
Totals	77.3	35.0	25.0

early June and young larvae move down the scale to enter the seeds (Fig. 6). Early-instar larvae feed on endosperms, but later become predacious. One larva entered two seeds not infested by other insects and left without devouring the endosperm. Remains of a number of *Megastigmus* larvae and five cecidogenous midge larvae were observed following the ravages of *Earomyia* in seeds and galls.

In autumn, full-grown larvae drop on the ground, where they overwinter in puparia in the litter (Fig. 7).

An average of 1.5 *Earomyia* larvae occurred in cones examined.

CONEWORMS

Larvae of *Laspeyresia laricana* Busck and *Dioryctria* sp. were encountered but not in sufficient num-

bers to be considered important seed destroyers.

DISCUSSION

The average loss to all insects was 60 seeds per cone (Table 1). The direct loss was easily assessed by counting the actual seed eaten. Indirect losses were estimated, and resulted from (a) feeding which deprived the seed of nutrients (scale midge), (b) fusion of seed to the scale preventing separation (cecidogenous midge), and (c) damage to seeds by predacious larvae searching for insect prey (cone maggot).

Seed chalcids were the most important pests and were responsible for almost 50% of the insect-caused loss.

Acknowledgement

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THE POLYMORPHISM IN *PHILAENUS SPUMARIUS* (L.) (HEMIPTERA: CERCOPIDAE) IN BRITISH COLUMBIA

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ABSTRACT

This paper analyses the distribution and relative frequency of the morphs of *Philaenus spumarius* in British Columbia, the populations being drawn from different biotic areas. It is shown that nine morphs occur in the province and of these, *marginellus* occurs only in the south-west corner; *marginellus* and *lateralis* occur only as females. The frequency of the morphs in the biotic areas of the province is not uniform; populations in dry areas differ significantly from those in wet areas. Populations taken from the various forest areas are not identical, nor are those from coastal areas.

Within a single biotic area, the frequency of morphs appears to be stable. No significant difference was determined between two samples taken sixteen years apart. Further, there appears to be no significant seasonal, daily or hourly change in the morph frequency in an area.

An experiment carried out on mating individuals failed to demonstrate a tendency for non-random mating and there was no evidence for the preferential mating of the rarer types.

INTRODUCTION

The Meadow Spittlebug, *Philaenus spumarius* (L.) is a common Holarctic insect which in the adult instar, exists in a number of distinct colour forms. The insect is able to utilize almost any succulent foliage, and has been recorded from over 400 species of plants (Doering, 1930a, 1930b). It is injurious to many crops and commercially may reduce hay yields by 20 to 50 per cent (Gyrisco, 1958; Anon, 1962), and stunt or kill individual legume plants (Weaver & Whitney, 1958). The biology has been studied by Weaver & King (1954) and Levigne (1959), while Wiegert (1964) has studied the population energetics and Halkka (1962a, 1962b), Owen & Wiegert (1962) and Hutchinson (1964) the morph frequency.

The polymorphism exhibited by this species seems to be stable, although it is little understood at present. Boring (1913) studied the various forms and could find no corresponding variation in the karyotype. Halkka (1962b) suggested that two or three colour inhibitor genes may be involved, some connected with "sex determiners", and Owen & Wiegert

(1962) suggest that some are sex linked. Hutchinson (1964) says that it seems not unlikely that a multiple allelomorphism is involved. Halkka *et al.* (1966) have recently carried out some crossing experiments and conclude that six major genes are involved and that "The six major genes may be allelomorphic with each other". There is a "possibility that the six major genes constitute a dominance hierarchy", and five of the genes "always manifest their effects in the female but never in the males" while the seventh "has a dominant mode of inheritance in both sexes". Halkka *et al.* (1966) further state that "The expressivity of the six major genes is remarkably independent of external factors, including food plants of the P and F₁ generations".

Hutchinson (1964) has stated that "While no clear understanding of the whole situation, which may prove to be one of the most dramatic examples of polymorphism, will be possible without genetic knowledge, more geographical and ecological information is sorely needed". This paper describes some observations on *P. spumarius* in British Columbia.

MATERIAL AND METHODS

Material in the Spencer Entomo-

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logical Museum at the University of British Columbia was studied to determine the distribution and frequency of morphs throughout the Province and to determine variations between different biotic areas. Some large collections made several years apart enabled a comparison of populations over a period of 16 years. Further, field collecting was done to study possible variation in morph frequency with season and over short periods of time.

An experiment to test the randomness of mating was performed on adult insects collected in August 1966, from a 15 yard by 60 yard area of vegetation at the University of British Columbia: the main plants on the area were *Plantago*, *Dactylis* and *Trifolium*. Field collected insects were placed in a cage containing cardboard strips for a resting surface. Mated pairs were removed in the first 30 minutes of the experiment and were kept isolated in individual 3" x 1" shell vials stoppered with cotton. All mated pairs were formed in

the first 30 minutes of the experiment, and such pairs were found to remain *in copula* from 30 minutes to two hours. A number of mating pairs were also obtained in the field, but there were too few for analysis.

The morphs were determined according to the patterns given in Halkka (1962a) and specimens compared with material taken in Finland and England. We have called the morph which is brownish with two pale costal spots on the corium, *spumarius*: this follows Edwards (1896) and the practice of most North American authors (Weaver & King, 1954; Owen & Wiegert (1962).

The biotic zones recognized in the paper follow the scheme of Munro & Cowan (1947). The main climatic features of these various zones are given in Table 1.

The method of Skory (Steel & Torrie, 1960, p. 368) was used in most calculations. Because of the scarcity of some morphs, lumping, as recommended by Siegel (1956), was necessary to operate the Chi-square test.

TABLE 1—Climatic data for various biotic zones in British Columbia.

BIOTIC ZONES	ANNUAL PRECIPITATION (inches)	TEMPERATURE (°F)		FROST FREE DAYS
		Mean Minimum	Mean Maximum	
Dry Forest	10-20	10-20	80-90	150-175
Cariboo Parklands	15-20	5-10	70-75	50-100
Columbia Forest	35-50	15-25	80-85	100-150
Subalpine Forest	40-50	-10 to 5	68-70	50-100
Coast Forest	50-150	30-35	60-70	200-250
Gulf Island	25-35	30-35	70-75	230-275
Puget Sound Lowlands	35-60	20-30	70-75	200-250
Queen Charlotte Is. (Masset)	71.11	20.5	65.0	168

RESULTS

a. Distribution and frequency of morphs

Nine different morphs were recognised in the material from British Columbia (Table 2). Of these, *marginellus* has been taken only in the Gulf Islands area (Victoria) and the Puget Sound Lowlands (Vancouver). The other morphs are fairly widely distributed. While the total number of males and females studied was about equal, both *lateralis* and *mar-*

ginellus were recorded only as females.

Table 3 gives the number of the various morphs from each biotic area studied; the Gulf Islands data are omitted since the sampling was known to be non-random. Analysis of the data in Table 3 show that the samples cannot be considered to have come from a single population ($\chi^2_{(15)} = 70.026$; $p \ll 0.001$).

While statistically it is not acceptable to reanalyse these data in vari-

TABLE 2—Distribution of morphs of *Philaenus spumarius* in British Columbia.

BIOTIC ZONE	MORPH TYPES								
	leucophthalmus	leucocephalus	lateralis	marginellus	fasciatus	spumarius	typicus	trilineatus	populi
Dry Forest _____	x	x	x		x	x	x	x	x
Cariboo Parklands _____		x			x	x	x	x	x
Subalpine Forest _____		x			x	x	x	x	x
Coast Forest _____		x	x		x	x	x	x	x
Gulf Islands _____	x	x	x	x	x	x	x	x	x
Puget Sound Lowlands _____	x	x	x	x	x	x	x	x	x
Queen Charlotte Islands _____						x	x	x	x

ous groupings, a case can be made from the biological point of view for doing so. We know that the various biotic zones in the province are climatically quite different and it is reasonable to ask if the polymorphism is different in these areas. Table 4 presents some comparisons which have been made. There would appear to be no difference between samples taken from populations within the wet areas (Queen Charlotte Is. + Coast Forest) and those from populations in dry areas (Cariboo Parklands + Dry Forest). However, populations in coastal areas appear to be dissimilar as do those in forest areas: the Dry Forest area is largely grassland and so was not included in the 'All Forest' analysis.

b. *Stability of morph frequency.*

The stability of the morph frequency with time was studied by

comparing two collections taken at Merritt in the Dry Forest area 16 years apart. Table 5 indicates that the two samples were not significantly different. This probably indicates a marked stability in the polymorphism, at least in this area.

Two samples taken at Burnaby in the Puget Sound Lowlands were compared to see if there was a seasonal change in the morph frequency in this area. The sample taken on 14 November 1962 was not significantly different from that taken on 29 July 1962 (Table 5). A similar comparison of catches taken on two consecutive days in September 1962 showed no significant difference.

Finally, to see if there was a change in morph frequency with temperature, photoperiod or other similar daily change, two samples were compared. The sample taken

TABLE 3.—Number of various morphs of *Philaenus spumarius* in different populations in British Columbia.

	MORPH TYPES								Total
	leucophthalmus	leucocephalus	lateralis	margineilus	fasciatus	spumarius	typicus	trilineatus	populi
Dry Forest	3	9	2	0	7	129	175	47	20
Cariboo Parklands	0	3	0	0	1	20	35	6	4
Subalpine Forest	0	4	0	0	9	110	127	9	12
Coast Forest	0	2	7	0	9	95	93	68	1
Puget Sound Lowlands	3	22	3	1	31	239	195	70	6
Queen Charlotte Islands	0	0	0	0	0	11	2	8	3
									1601

TABLE 4—Difference between populations of *Philaenus spumarius* from various areas in British Columbia.

GROUP	BIOTIC ZONES	DEGREES OF FREEDOM	CHI-SQUARE	p
All of B.C.	All zones	15	70.026	$\ll 0.001$
Low Coastal Area	Queen Charlotte Is. Coast Forest Puget Sound Lowlands	6	56.485	$\ll 0.001$
Wet Coast	Queen Charlotte Is. Coast Forest	3	1.196	0.7-0.5
Dry Interior	Cariboo Parklands Dry Forest	3	0.461	0.95-0.90
Dry Interior + Dry Coast	Cariboo Parklands Dry Forest Puget Sound Lowlands	6	17.527	0.01-0.001
All forest	Subalpine Forest Coast Forest Queen Charlotte Is.	6	75.240	$\ll 0.001$

around 14:00 hours did not differ significantly from that taken around 18:00 hours (Table 5).

c. Randomness of mating

Table 6 presents the data obtained from 24 mated pairs in the laboratory mating experiment. An analysis of these data suggest that the mating is random ($\chi^2_{(4)} = 4.944$; $0.30 > p > 0.20$). Further, a comparison of these data with the expected pairing based

on the frequency of morphs in the original population, indicates that the pairs obtained were randomly drawn from the population ($\chi^2_{(4)} = 7.43$; $0.20 > p > 0.10$).

DISCUSSION

Hutchinson (1964) says that *P. spumarius* may constitute one of the most dramatic examples of polymorphism in animals, but a survey of the literature shows that it has not so

TABLE 5—Comparison of samples of *Philaenus spumarius*.

PLACE	DATE	MORPH. GROUPING				TOTAL	DF	CHI ²	p
		I	II	III	IV				
(1) Samples taken 16 years apart									
Merritt	20.viii.32	3	12	29	4	48			
Merritt	15.viii.48	11	19	34	11	75	3	4.1	0.3-0.2
		14	31	63	15	123			
(2) Samples taken 3 months apart									
Burnaby	29.vii.62	8	8	6		22	2	0.98	0.7-0.5
Burnaby	14. x. 62	3	6	5		14			
		11	14	11		36			
(3) Samples taken 1 day apart									
Burnaby	7. ix. 62	7	29	15	3	54	3	4.5	0.3-0.2
Burnaby	8. ix. 62	4	16	18	6	44			
		11	45	33	9	98			
(4) Samples taken 4 hours apart									
Burnaby	7.ix.62 (14:40 pm)	7	29	15	3	54	3	5.3	0.2-0.1
Burnaby	7.ix.62 (18:40 pm)	6	15	19	6	46			
		13	44	334	9	100			

TABLE 6 — Mating pairs of *Philaenus spumarius* obtained in Laboratory experiment. Original population: 39 ♂ 51 ♀ *spumarius*, 11 ♂ 12 ♀ *trilineatus*, 8 ♂ 15 ♀ *populi*.

Females	Males		
	<i>spumarius</i>	<i>trilineatus</i>	<i>populi</i>
<i>spumarius</i>	11	3	1
<i>trilineatus</i>	3	3	0
<i>populi</i>	1	1	1

far been recognised as such, being absent from the reviews of Ford (1965a, 1965b). Halkka *et al.* (1966) have shown that the polymorphism has a genetic basis, but it is clear that much remains to be learned about the situation. The present information suggests that the genetic control is not a very simple one.

A study of the various morphs in British Columbia and the comparison of these with specimens from eastern North America and western Europe, shows that there is considerable variation in the colour pattern of the types. The same morphs from different parts of the range of this insect, appear slightly different and it is not always easy to separate them.

The present study shows that the morph frequency is not the same throughout British Columbia, and suggests that there is a difference between populations in dry and in wet areas. While climate would appear to have some effect on the polymorphism, it is not possible to define the environmental factors more precisely at the present time. Since no change was detected between samples taken at different times of day, the situation in *P. spumarius* would seem not to be so simple as that in *Colias* (Lepidoptera), where Hovanitz (1953) has shown a correlation with temperature.

We were unable to detect a seasonal change in the morph frequency in an area. Owen & Wiegert (1962) working in Minnesota likewise found no seasonal variation in the frequency of *populi* (= *pallidus*) and *spumarius*. On the other hand, Dobzhansky (1943, 1948) working on

Drosophila and Timofeef-Ressovsky (1940) working on *Adalia* have shown marked seasonal variation in the polymorphism in these insects.

The fact that two samples taken in the same area over a 16 year period showed no significant difference, can be taken to indicate that the polymorphism is probably stable, at least in that area. Owen & Wiegert (1962) showed a similar stability over a four year period in an abandoned field in southeastern Michigan. However, studies on the frequency of morphs over long periods in other animals have usually demonstrated marked changes (see Dobzhansky, 1958; Komai, 1956; Clark & Murray, 1962a, 1962b).

There seems to be little predation on *spumarius* populations (Weaver & King, 1954) and thus the selection would appear to be rather different from that described in *Biston betularia* (Lepidoptera) (Kettlewell, 1961) and *Cepaea* (Mollusca) (Cain & Sheppard, 1954). Nevertheless, Owen & Wiegert (1962) state that the relative frequency of the forms may be determined through selection by predators.

In the experiment on randomness of mating, the results seem to indicate that mating is indeed random. Thus preferential mating, which is reported to occur in *Panaxia dominula* (Lepidoptera) (Sheppard, 1952) seems not to be present in *P. spumarius*. Further, there is no evidence that there is any preferential mating of the rarer types, as recently suggested in *Drosophila* by Ehrman *et al.* (1965).

Thus our study indicates that factors cited as the main selection forces

in other examples of polymorphism, seem not to apply in *P. spumarius*. At the present time, one can only state that the selective advantage of the polymorphism in this insect is unknown. The results obtained so far on populations in British Columbia suggest that further studies on the temperature and humidity prefer-

ences and tolerances of the various morphs may be worthwhile.

Acknowledgements

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MOISTURE AND FAT CONTENT DURING THE ADULT LIFE OF THE AMBROSIA BEETLE, *TRYPDENDRON LINEATUM* (OLIV.)

By W. W. NIJHOLT¹

ABSTRACT

Depletion of fat deposits during the long hibernation period of the adult ambrosia beetle, *Trypodendron lineatum* (Oliv.), amounts to about one quarter of the original fat content. The fat loss during flight activity appears to be also about one quarter of the amount present at the start of hibernation.

Experiments with beetles stored at different temperatures indicate that during a long cool spring the rate of fat loss increases, probably affecting the vigor of the population during subsequent flight and brood establishment.

INTRODUCTION

Many insects derive energy for metabolic activity from stored lipids (Fast, 1964), supplies of which are likely to vary during adult life. To understand individual behaviour patterns, a knowledge is required of the relationship between the fat content of the insect and its behaviour. Atkins (1966) demonstrated such a relationship in a scolytid, and stressed the need for studies that penetrate to the physiological basis of behavioural variation.

The ambrosia beetle, *Trypodendron lineatum* (Oliv.), spends a major part of its adult life in hibernation. Climatic conditions influence the length of the hibernation period and thus affect the utilization of stored lipids which in turn affects the subsequent flight and attack activities. This investigation was undertaken to learn more about the depletion of fat

during hibernation and the flight period that follows.

METHODS AND MATERIALS

The data were obtained from beetles collected from duff or bark in standing timber around logging areas near Lake Cowichan, B.C., between August 1965 and July 1966 (Dyer and Kinghorn, 1961). The heated pan method described by Hadorn (1933) and Kinghorn and Chapman (1959) was used for recovering the beetles. Moisture and fat were determined by drying in an oven and extracting with petroleum ether in a Soxhlet unit (Nijholt, 1965). In this presentation, values for fat, or lipids, represent substances extractable in petroleum ether.

To check the speed and efficiency of the extraction, groups of 25 beetles were dried, weighed, and extracted for various lengths of time up to six hours. The amount of fat loss

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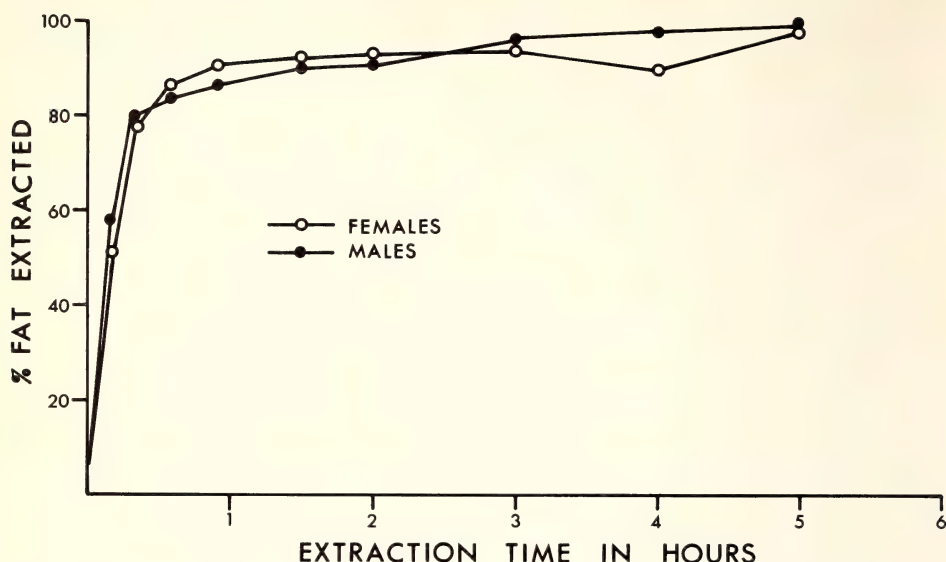


Fig. 1. Fat extracted in petroleum ether from male and female adult ambrosia beetles, *Trypodendron lineatum*, in groups of 25.

was determined for all the groups, which were then extracted again for the time required to bring the total extraction period to six hours.

Fig. 1 shows that more than half of the total fat was removed within the first 10 minutes, and that more than 99% was extracted in five hours. Six hours was therefore considered to be sufficient to extract all the fat.

During the period of hibernation of the ambrosia beetle, samples were taken at intervals from the same forest margin to determine the reduction of stored fat deposits. Samples of beetles in flight or crawling near attractive logs were taken during the subsequent flight period. All samples were kept at 0°C after collection and were processed as soon as possible, so that the results closely represent the condition of the beetles at the time and place of sampling. Unless otherwise indicated, water and fat determinations were made for individual beetles, to provide a measure of the variability within the samples. The weights were determined to within 0.01 mg.

Samples of flying beetles were ob-

tained by "live-trapping", using a glass-barrier flight trap, with a trough leading to a slit in a horizontally placed metal cylinder with clear vinyl plastic ends. The beetles crawled toward the light at the ends of the cylinder. Little mortality occurred when the beetles were collected regularly. The traps were set up in forest stands near sources of attractive log odour.

The fat content decreased gradually during hibernation (Fig. 2), while the fat free extracted weight remained at the same level indicating that lipids were utilized. This was accompanied by an increase in moisture content. The beetles caught during the flight period cannot be considered as members of the above population since they were captured several miles from the site of overwintering. Nothing is known of where the flying beetles came from or how long they had flown. The results indicate that the beetles use up about one quarter of their stored fat during hibernation and a similar amount during post hibernation dispersal. Consequently, the beetles arrive at

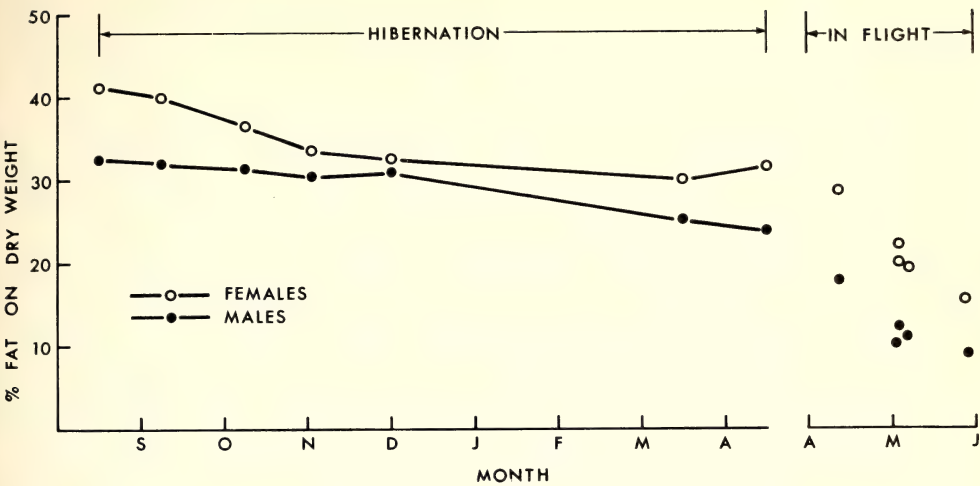


Fig. 2. Percentage of fat of dry weight of *Trypodendron lineatum* (Oliv.) during hibernation and flight period.

their new brood site with about one half of their original fat reserves.

Histograms of the distribution of individual beetles into classes of different fat content at different times show that the number of lean beetles increased during the first part of the collection period and then declined (Fig. 3), suggesting that some of the weaker beetles did not survive the hibernation period and therefore the population quality would be altered to some extent. It is not known how many non-survivors were old adults, going through a second hibernation.

To determine the fat content of beetles during their flight period, the possibility of using "wet-trap" catches, as described by Chapman and Kinghorn (1955, 1958) was considered, but results from these samples were not considered reliable.

A study was made of changes in fat content during laboratory storage of beetles at 4°C for several months. The beetles do not walk or fly at 4°C, but some of the stored fat is consumed by metabolic activity. A sample of beetles collected in April 1966 was sorted into groups of approximately 80 individuals and these

were stored in plastic bags of bark flakes in a darkroom at 4°C. A control sample was stored similarly at 0°C. At monthly intervals for three months the dry weight, moisture content and fat content were determined. One group was kept stored for an additional three months. The results are presented in Table 1 with data from samples of beetles collected in the spring of 1965 and stored for six months at 0°C.

Table 1 shows that considerably more fat is utilized at 4°C than at 0°C. At 4°C conditions simulate a prolonged, cool spring during which the beetles could conceivably lose some vigor, while awaiting sufficiently warm weather for flight and attack. The relationships between the amount of fat remaining after overwintering, and the flight and brood production remain to be established.

These studies indicate no more than quantitative changes in fat. The qualitative aspects of the lipid metabolism of the insect during its long adult life await further study and should provide some insight into the relationship between the various aspects of behaviour and stored energy.

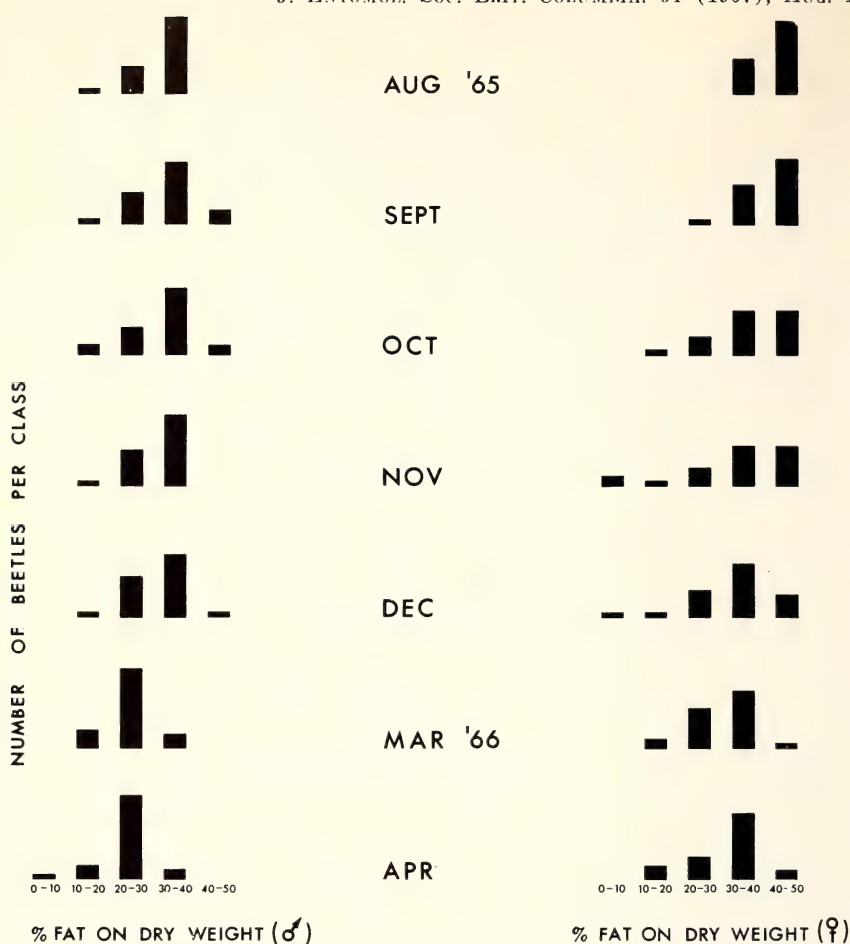


Fig. 3. Histogram of percentage of fat of dry weight of *Trypodendron lineatum* (Oliv.) during hibernation.

TABLE 1—Average values in mg of moisture, dry weight and fat, with percentage fat of groups of 25 ambrosia beetles, *Trypodendron lineatum*, stored for periods up to six months at 0° or 4°C.

	Time stored, days	Weight of moisture	Fat free weight	Weight of fat	Fat % of dry weight
Females					
	0	2.09	1.28	0.52	28.3
	30	2.14	1.15	0.54	30.7
	60	2.06	1.12	0.35	21.8
	90	2.14	1.10	0.36	22.7
	180	2.28	1.15	0.26	17.5
	180 ¹	2.34	1.15	0.45	27.3
	180 ²	2.16	1.10	0.37	22.7
Males					
	0	1.89	1.09	0.33	22.6
	30	1.88	1.01	0.31	22.1
	60	1.84	0.84	0.15	11.9
	90	2.04	1.03	0.18	14.4
	180	2.03	1.03	0.08	7.1
	180 ¹	2.05	0.98	0.24	18.6
	180 ²	1.95	1.06	0.27	19.7

¹Control sample stored at 0°C.

²Sample collected in the spring of 1965 and stored at 0°C.

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SOLENOBIA TRIQUETRELLA HUBNER, A FLIGHTLESS PARTHENOGENETIC MOTH, IN BRITISH COLUMBIA (LEPIDOPTERA: PSYCHIDAE)

H. B. LEECH¹ AND B. A. SUGDEN²

ABSTRACT

The occurrence of *Solenobia triquetrella* Hübner at Vernon, B.C., with notes on its habits and a brief description of the ultimate instar larva and adult is contained herein. Evidence indicating that *S. triquetrella* may have been introduced is presented.

INTRODUCTION

Small sand-covered, elongate cases containing insect larvae were first found by the senior author at Vernon during 1941, 1945 and 1946. Adults reared subsequently were designated as *Solenobia triquetrella* Hübner. The following notes are presented since we do not know of published records of this species in North America.

OBSERVATIONS

On April 17, 1945, hundreds of these casebearers were climbing walls, maple trees, and along the underside of fence rails not far from the site at Vernon where these insects had been discovered in 1941. Nearly 1000 cases were collected from tree branches, tall dead grasses and the underside of boards lying on the ground. Almost all produced moths, every one a female; many laid eggs which hatched. There were no parasites from any stage of *Solenobia*.

By April 18, 1946, at the same places, mature larvae were again numerous. On April 25 many cases were firmly attached to sites similar to those of the previous year. Pupae, a few adults, and eggs were present. Fifteen hundred cases were collected and caged; again almost all produced moths which laid numerous eggs, but no male moths or parasites emerged. The eggs began to hatch on May 12.

Attempts to rear the larvae on dry rotted wood, decaying leaves and on

freshly cut pieces of couch grass were unsuccessful.

The following is a description of the insect as it occurred at Vernon:

Larva: The fully grown larva (Fig. 3) appears early in April; it attaches the open end of the case firmly with a mass of silken threads to the substrate so that it usually hangs downward (Fig. 1). The larva then reverses its position in the case to face the distal end which is closed by three flaps fitting neatly, yet loosely, together.

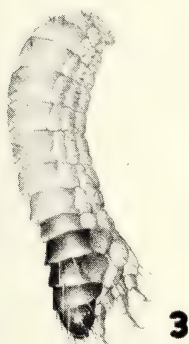
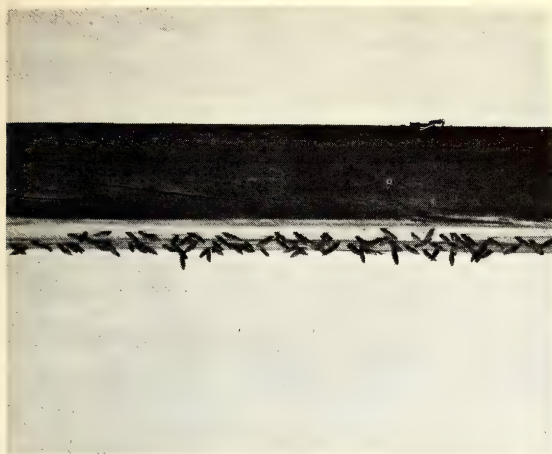
Pupa: The mature larva pupates within the anchored case in mid April; the stage lasts about a week. Shortly before the moth emerges the pupa moves through the flaps of the case until only the apical abdominal segment with cremaster hooks remains within (Figs. 2, 4). Most of the body is filled with eggs which are almost as large as those laid by the adult.

Imago: The moth is 3 to 4 mm long, wingless and mouse-grey, with whitish scales along the sides. Upon emergence there is a dense brush of long wavy hair across the apparent 5th and 6th abdominal segments (Figs. 5, 6).

The moth is parthenogenetic, and begins egg laying soon after emerging. As she oviposits, the moth ingests air, gradually inflating the anterior half of her body so that the membranous areas between segments are semi-transparent. The resulting pressure helps to expel the eggs. If the distended body is punctured with a pin, it deflates like a balloon, with-

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Figs. 1 - 6.—*Solenobia triquetrella* Hübner at Vernon, B.C.

Figure 1.—Larval-pupal cases on underside of fence rail.

Figure 2.—Larval-pupal cases attached to broken tip of a small living branch of *Acer negundo* L. Projecting farthest downward are two empty pupal skins; females at upper left, lower middle and far right are laying eggs in empty cases.

Figure 3.—Mature larva.

Figure 4.—Empty pupal skin attached to case after female has emerged.

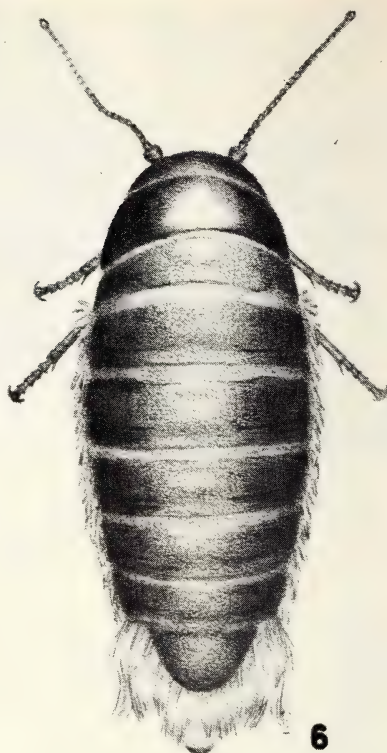


Figure 5.—Lateral view of freshly emerged female showing full pad of ventral abdominal hairs and retracted ovipositor.

Figure 6.—Freshly emerged female—dorsal view.

out loss of body fluid.

The moth uses the larval-pupal case as a receptacle for the eggs, inserting the ovipositor past the empty pupal skin without dislodging it. The first eggs are laid at the caudal end, sometimes even within the old larval skin which remains in the case. During oviposition hairs from the abdominal brush are plucked out a few at a time by the prehensile tip of the telescopic apical abdominal segments and placed with the eggs. On completion of oviposition the case is full of eggs and hairs and the abdominal brush of the moth has disappeared.

DISCUSSION

In 1927 Ronald Buckell sent Dr. J. McDunnough of Ottawa, a number of specimens reared from cases found on a fence rail at Vernon: Dr. Mc-

Dunnough noted that "... they might belong to the genus *Solenobia* as the simple type of case covered with earth granules point in this direction."

Specimens were sent to Dr. W. Sauter of Zurich, specialist on the genus *Solenobia*. He replied: "The shape of the cases and the female does not leave a doubt that it must be *Solenobia triquetrella* Hbn. This species is widely spread in Europe and I also saw specimens of it from North America: Montreal. Also the specimens of Montreal belong to the parthenogenic form. As Prof. Seiler stated, it was the tetraploid race. It would be very interesting to know the chromosome number of your race . . . I do not know more about the distribution of *S. triquetrella* in

America and wonder if the species really is introduced. If not, it should be possible to find also the bisexual form in parts of the continent which have not been covered with ice during the last glacial epoch."

The species could be widely distributed in British Columbia but unreported. The larval cases are small, inconspicuous, and unlikely to attract attention unless numerous. However considering the hundreds which have been found on house walls or porch ceilings it is surprising that they have not been noticed by worried householders. We found a few cases at Salmon Arm, but only after persistent searching, and because of our knowledge of larval habits.

The late E. P. Venables said that he had found cases presumably of this species near Kelowna, B.C. on the underside of bridge railings. If Venables' record is *S. triquetrella*, then the species is known from four towns over a north-south linear distance of 65 miles with Vernon near the midpoint. Considering how often boards, packing cases and vehicles, any of which may have been standing in an infested area, are moved about, the distribution seems reasonable for an

introduced species.

Two facts suggest that *S. triquetrella* is introduced: (a) despite years of searching and intensive collecting, larval cases have only been found in towns; (b) no parasite was recovered from nearly 2,000 viable larvae and pupae from a population known to have been present for at least 20 years. *Addendum*—When the above manuscript was read at the March, 1966 Annual Meeting of the Entomological Society of British Columbia, members in the audience gave additional records which are likely to be of *S. triquetrella*. Mr. P. Zuk said he had seen similar larval cases at Vancouver; Mr. C. L. Neilson reported that he had found cases on the walls of a Naramata cannery. Dr. H. A. Madsen recalled that a *Solenobia* moth was reared from egg to adult at Berkeley, California, the eggs having come from a mountain orchard at an altitude of 3,000 feet.

Acknowledgements

We are grateful to the persons mentioned in the text, and to Messrs. W. G. Mathers and S. H. Farris for help in collecting. The photographs were taken by Harry Andison in 1946; the drawings are by B. A. Sugden. The writers also thank Dr. L. H. McMullen for editing the text.

DISTRIBUTION AND HOSTS OF SOME HORNTAILS (*SIRICIDAE*) IN BRITISH COLUMBIA

E. V. MORRIS¹

ABSTRACT

Locality records and coniferous hosts of seven species of Siricidae in the genera *Urocerus*, *Sirex* and *Xeris* are recorded for British Columbia. Six species were reared from western larch, five from alpine fir and only one or two from seven other hosts. The life cycle was one or two years and major emergence was between mid-July and early August.

Horn-tails are widely distributed in the coniferous forests of Canada, infesting conifers of low vigour, those damaged by fire or other agencies, and recently felled trees. Little is known of their life history, habits,

hosts, and distribution in British Columbia. Adults are active during the summer and oviposit in the sapwood. The larvae feed in the wood and take one or more years to complete their development to the adult stage.

TABLE 1. Emergence period and length of life cycle of seven species of horn-tails from caged log sections of nine coniferous hosts, Vernon, B.C.

1924 - 1930 and 1964 - 1966					
Host	Trees sampled, no.	Insect reared	Specimens, no.	Emergence period*	Life cycle, yr.
Western larch	24	<i>Sirex juvencus californicus</i> (Ashm.)	1	Aug 30	1
		<i>Urocerus albicornis</i> (F.)	8	Jun 21— Jul 15	2
		<i>U. gigas flavicornis</i> (L.)	1	Aug 10	1
		<i>U. californicus</i> Nort.	1	Jun 19	1
		<i>Xeris morrisoni</i> (Cr.)	1	Jul 25	1
		<i>X. spectrum</i> (L.)	6	Jul 13— Aug 30	1
Ponderosa pine	12	<i>S. j. californicus</i> (Ashm.)	4	Jul 13— Aug 25	2
Western white pine	11	<i>U. californicus</i> Nort.	2	Jul 11— 20	2
Lodgepole pine	19	<i>S. j. californicus</i> (Ashm.)	14	Aug 4— Sep 3—	1
		<i>S. j. juvencus</i> (L.)	1	Aug 1	1
Alpine fir	15	<i>S. cyaneus</i> F.	13	Jul 15— Aug 15	2
		<i>S. j. juvencus</i> (L.)	3	Jul 17— Aug 15	2
		<i>U. californicus</i> Nort.	5	Jul 15— 22	2
		<i>U. albicornis</i> (F.)	2	Jul 22— 25	2
Alpine fir		<i>X. spectrum</i> (L.)	1	Jul 15	2
		<i>X. spectrum</i> (L.)	1	Sep 7	1
Douglas-fir	30	<i>U. albicornis</i> (F.)	2	Jul 15— 17	2
		<i>U. californicus</i> Nort.	6	Jul 17— 28	1
Western hemlock	8	<i>S. cyaneus</i> F.	24	Jul 15— Aug 1	2
White spruce	15				
Western red cedar	6	<i>U. albicornis</i> (F.)	1	—	—

*In some instances there are only one or two emergence records.

¹ Forest Entomology Laboratory, Vernon, B.C.



Fig. 1. Localities where *Urocerus* spp. have been collected in British Columbia.

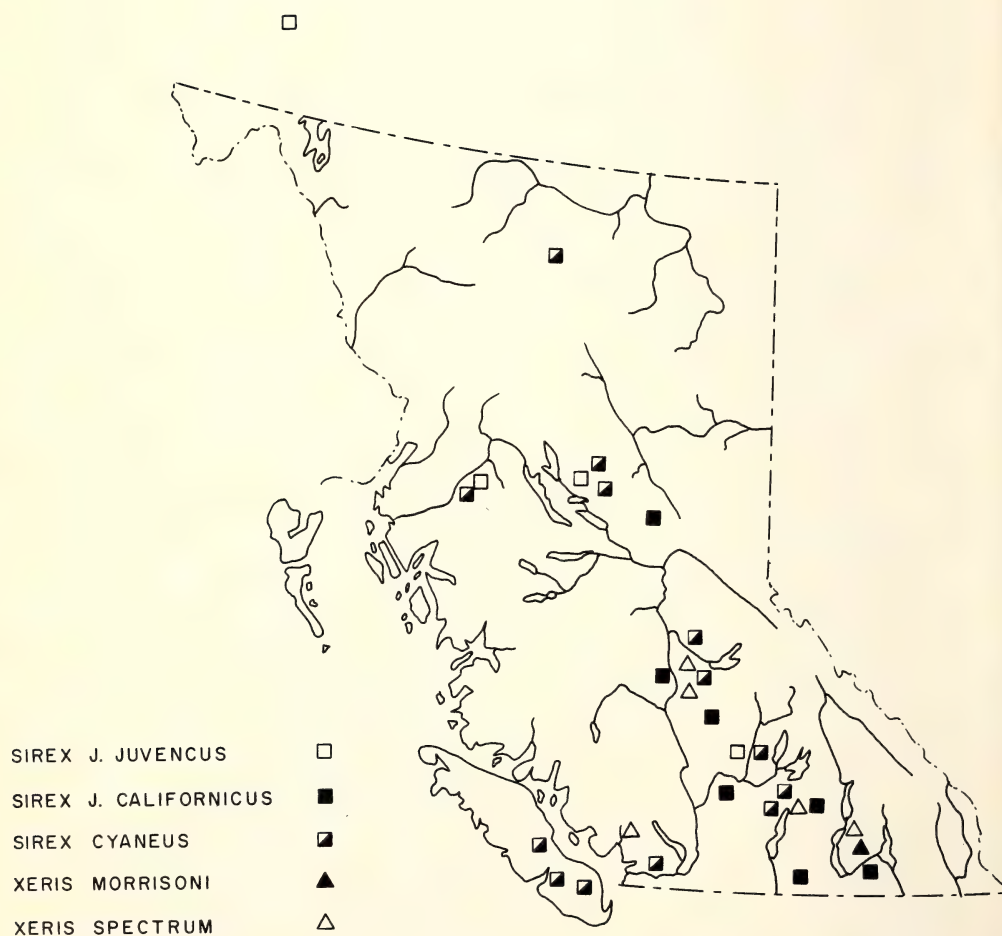


Fig. 2. Localities where *Sirex* spp. and *Xeris* spp. have been collected in British Columbia.

Host trees and emergence dates of horntails were obtained from wood-borer studies conducted by personnel of the Forest Entomology Laboratory at Vernon between 1924 and 1930 and from 1964 to 1966. In the latter study, trees of 11 species of conifers were felled in the spring at a number of localities in interior British Columbia. In the autumn of the year of felling, three 2-foot-long sections ranging from 8 to 16 inches in diameter were cut from the trees and placed in cages outdoors. Log sections were also taken from logging slash when the date of logging was known. Records were kept of the numbers of horntails and their emergence dates. Seven species were reared from log sections of nine species of conifers from interior British Columbia (Table 1). The greatest number emerged between mid-July and early August. The earliest was *Uro-*

cerus californicus emerging June 19 from western larch infested the previous summer at Heckman Creek, 40 miles east of Vernon; the latest was *Xeris spectrum* emerging September 7 from Douglas-fir infested the previous summer at Trinity Valley.

Locality records for seven species and one sub-species of horntails were obtained from Forest Insect and Disease Survey data from coastal and interior British Columbia, and from the special rearing projects (Figs. 1 and 2). More extensive sampling will be required to obtain the true range of most of these horntails.

Acknowledgements

The author is indebted to D. A. Ross for permission to use the data on siricids obtained from his wood-borer investigations during 1964 to 1966. The siricids were identified by H. E. Milliron, Entomology Research Institute, Ottawa and B. A. Sugden, Forest Entomology Laboratory, Vernon, B.C.

NOTE ON A SPRUCE BARK WEEVIL, *PISSODES ALASCENSIS* HOPKINS (COLEOPTERA: CURCULIONIDAE), IN BRITISH COLUMBIA

D. F. DOIDGE¹

ABSTRACT

Pissodes alascensis Hopkins ranges throughout interior British Columbia and into Yukon Territory. Spruces are preferred hosts. Weevils reared at 1,300 ft. elevation had a 1-year life cycle, but most of those reared at 4,000 ft. elevation had a 2-year life cycle. The latter passed the first winter in the larval stage in the inner bark and the second as callow adults in pupal chambers in the wood. Emergence ranged from the end of May into September.

Pissodes alascensis was described by Hopkins (1911) from a type specimen collected near Koyukuk River, Alaska. He surmised that this species attacked spruce and ranged through Yukon Territory and interior British Columbia. This report gives information on hosts, emergence periods, life cycle and distribution in British Columbia. Sources of data include unpublished rearing records from experiments at Trinity Valley and

Lorna, B.C., in 1925-30, at Vernon, B.C., in 1965-66, and pinned specimens in the reference collection at the Forest Entomology Laboratory at Vernon.

In the period 1925-30, data on spruce bark weevils were obtained from experiments in which wood and bark-boring Coleoptera were reared in caged logs of Engelmann spruce, *Picea engelmanni* Parry. Emergence of *Pissodes alascensis* ranged from the end of May until September 21. Total emergence at Trinity Valley

¹ Forest Entomology Laboratory, Department of Forestry and Rural Development, Vernon, B.C.

(2,200 ft elevation) occurred the year after infestation; at Lorna (4,000 ft elevation) the major emergence occurred the second summer after infestation (Table 1). Most of the weevils reared at 4,000 ft passed the first winter in the larval stage and

the second as callow adults in pupal chambers.

During the summer of 1965 three 2-ft-long sections of various species of conifers were collected in interior British Columbia for wood-borer studies. The trees were felled early in

TABLE 1—*Pissodes alascensis* reared from three Engelmann spruce logs at Trinity Valley (2,200 ft elevation) and Lorna (4,000 ft elevation) 1925-30.

Locality	Date tree felled	Date caged	Adult emergence		
			No.	Year	Range
Lorna	1924	Jun 10, 1925	16	1925	Jun 16-Sep 13
		Jul 16, 1926	98	1926	Jul 17-Aug 28
Trinity Valley	Jun 1927	May 24, 1928	6	1928	May 26-Aug 13
	1929	May 23, 1930	32	1930	Jun 24-Sep 21



Fig. 1. Pupal chambers of *Pissodes alascensis* in black spruce.

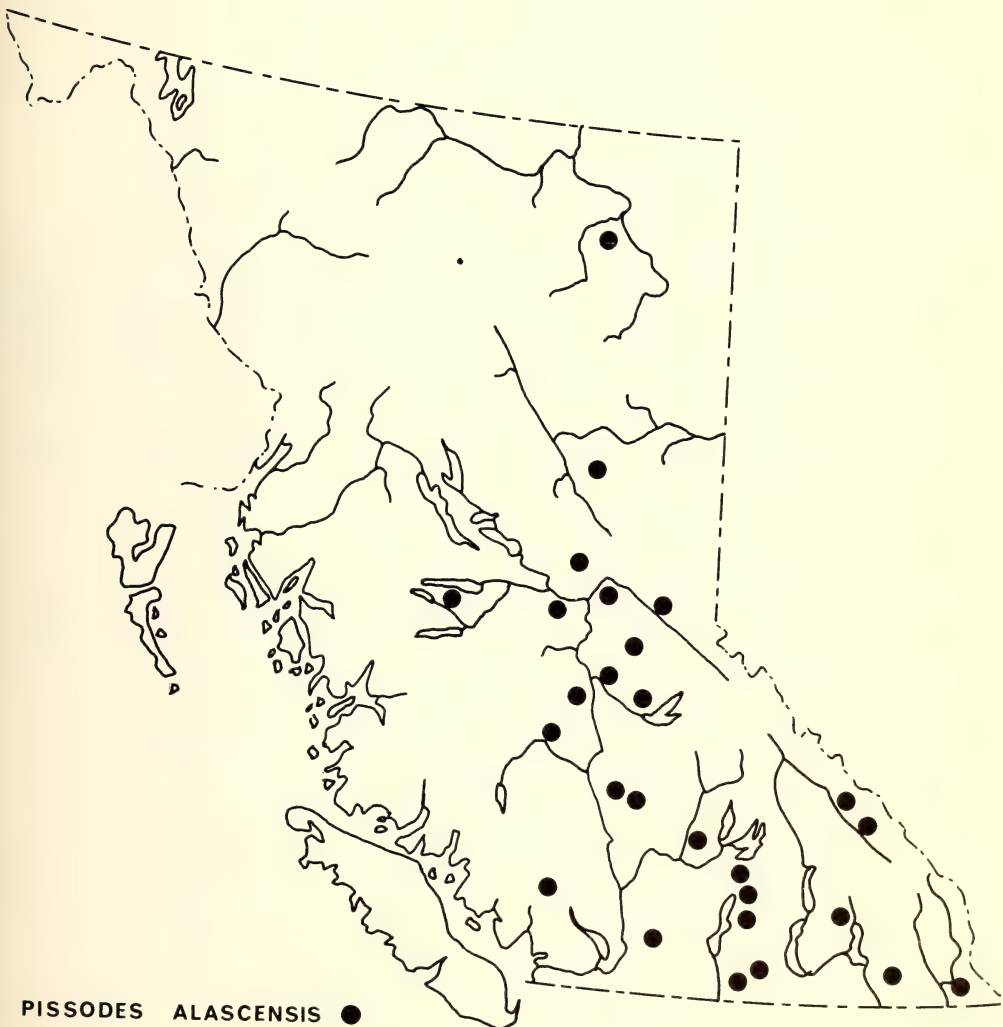


Fig. 2. Localities where *Pissodes alascensis* Hopk. has been collected in British Columbia and Yukon Territory

TABLE 2—*Pissodes alascensis* reared at Vernon, B.C. (1,300 ft elevation) 1965-66

Locality	Host (spruce)	Date trees felled (1965)	Date sections caged (1965)	Adult emergence	
				No.	Range (1966)
Pine Pass	white	Jun 22	Aug 23	8	Jun 19- Jul 17
Bednesti L.	black	Jun 25	Aug 24	50	Jun 17- Jul 28
Donald	Engelmann	Jun 23	Aug 27	32	Jun 19- Jul 13

the summer and caged at Vernon (1,300 ft. elevation) in August, 1965. *Pissodes alascensis* adults were reared only from Engelmann, white, *Picea glauca* (Moench) Voss, and black spruce, *P. mariana* (Mill.) BSP.

Emergence ranged from June 17 to July 28 (Table 2) and was completed 1 year after infestation. The logs were peeled to expose the larval galleries and pupal chambers. The larvae had fed on the inner bark but had not scored the wood except during construction of pupal chambers. In black spruce, the chambers were excavated to a depth of 2.5 mm (Fig. 1). There were 57 pupal cells in 1 ft² of a black spruce bole 127 mm in dia-

meter with bark 4.0 mm thick. No similar information was available for Engelmann or white spruce.

Forest Insect and Disease Survey records show that *Pissodes alascensis* ranges throughout interior British Columbia and north at least as far as Mile 60 on the Mayo Road, Yukon Territory. The weevil was also collected at Alta Lake, B.C., (Fig. 2).

Acknowledgements

The author is indebted to D. A. Ross for permission to use the data on *Pissodes* obtained from his wood-borer investigations during 1965-1966. The *Pissodes* were identified by S. G. Smith, Entomology Research Institute, Sault Ste. Marie, and B. A. Sudgen, Forest Entomology Laboratory, Vernon, B.C.

Reference

Hopkins, A. D. 1911. 1. Contributions toward a monograph of the bark-weevils of the genus *Pissodes*. U.S. Dep. Agric. Tech. Ser., 20 (1) p. 61.

BOOK REVIEW

Insect Pests. H. S. Zim and G. S. Fichter. New York, Golden Press, 1966. p. 160. \$1.35 in Canada.

Here, at last, is the answer for impoverished students and perennial inquirers who need a book on insect pests that is reliable, readable, and cheap. A generalized book is no substitute for local, explicit recommendations, and this one gives no more than generalized advice for dealing with 350 pests over so varied an area as middle North America. It does contain an immense amount of factual and biological information and gives broad principles of control. It provides the maximum of economic entomology for the minimum money.

The all-important breakdown and organization are well - thought - out. The sections with the number of pages are as follows: Introduction, numbers, relatives and development of insects (6); controlling insects by natural, biological, mechanical, chemical and new methods (14); household pests (14); insects that bite or sting (10); pests of: pets, poultry and livestock (13); vegetable crops (25); flowers and shrubs (12); field and forage crops (22); fruits and fruit trees (19); forest and shade trees (7); stored products (8); an index of scientific names (3); and common names (4).

Compared with the earlier 'Insects', this book presents only one-

half as much basic entomology, and this is a pity. No space is wasted. Nicholas Strelakovsky's coloured pictures tend to be small and crowded but they are accurate and adequate. Crowding accounts for the only real error noted (p. 94). The writing degenerates at times into the telegraphic, but it is generally hard to fault. The printing and quality of the pictures are somewhat uneven and not up to the high standard of earlier issues in the series. There is a blue-green cast to the inks used, the letterpress fades into grey in places, and the paper is thinner and shiny. At the foot of each page the section is given with the page number. The annoyance at finding these often crowded off the page by pictures running out to the margin, indicates their usefulness for quick reference. The captions and text seldom repeat each other, and there are good cross references between sections. Measurements are given in decimal fractions of one inch. An inch scale divided into tenths would be more useful than the cm and mm scale given at the margin on p. 158.

In the space available, the coverage is maximal, and includes, naturally, a number of non-Canadian pests. The mites are well covered and there are illustrations and descriptions of such non-insect pests as jumping and black widow spiders, millipedes, centipedes, sowbugs, slugs,

and snails. Of interest is the threatening cereal leaf beetle, *Oulema melanopa*.

The treatment of pesticides deserve mention. The introductory section deals with formulations, stomach poisons, and contact insecticides, covering inorganics, natural organics and the synthetics. Under chlorinated hydrocarbons, DDT rates 210 words, and there are short paragraphs on or mention of methoxychlor, TDE, BHC, lindane, toxaphene and the cyclodienes as a group. Under organo-phosphates, there is mention of parathion, demeton, TEPP, malathion, DDVP, diazinon, ronnel and dicapthon. Fumigants include CS², dichloropropene and dichloropropane, HCN, CH³Br, paradichlorobenzene and naphthalene. There is a paragraph on oils, another on repellents, and a final short section on sterilants, hormones and sorptives. Over and over throughout the text, the theme is repeated: "Do not use insecticides after the plant begins to form edible parts"; "Timing is critical . . ."; "Local agricultural agents can advise . . ."; "Consult an agricultural agent . . ."; "Follow directions carefully"; and so on.

All Golden Nature Guides contain 160 pages. To distil into this predetermined compass a significant part of the available information, is a *tour de force*.

H. R. MACCARTHY

METRIC CONVERSION

Contributors of papers on laboratory studies should use the metric system exclusively. Use of the metric system in reporting the results of field studies is a desirable ultimate objective. Since it is difficult to replace immediately such standard concepts as lb/acre by the unit kg/hectare, yards by meters, or miles by kilometers, the following table of conversion factors is presented.

1 in.=2.54 cm	1 ft ³ =28.3 dm ³	1 cm=0.394 in
1 yard=0.914 m	1 acre=0.405 hectares	1 m=3.28 ft=1.094 yards
1 mile=1.61 km	1 lb/acre=1.12 kg/hectare	1 km=0.621 mile
1 lb.=453.6 g	1 lb/in ² (psi)=70.3 g/cm ²	1 kg=2.2 lb
1 gal (U.S.)=3.785 liters	1 lb/gal (U.S.)=120 g/liter	1 liter=0.264 gal (U.S.)
1 gal (Imp)=4.546 liters	1 lb/gal (Imp)=100 g/liter	1 liter=0.220 (Imp)
	1 dm ³ =0.0353 ft ³	
	1 hectare=2.47 acres	
	1 kg/hectare=0.89 lb/acre	
	1 g/m ² =0.0142 psi	
	1 g/liter=0.83 lb/100 gal (U.S.)	
	=1000 ppm	
	1 g/liter=1 lb/100 gal (Imp)	

NOTICE TO CONTRIBUTORS

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The style, abbreviations and citations should conform to the Style Manual for Biological Journals published by the American Institute of Biological Sciences.

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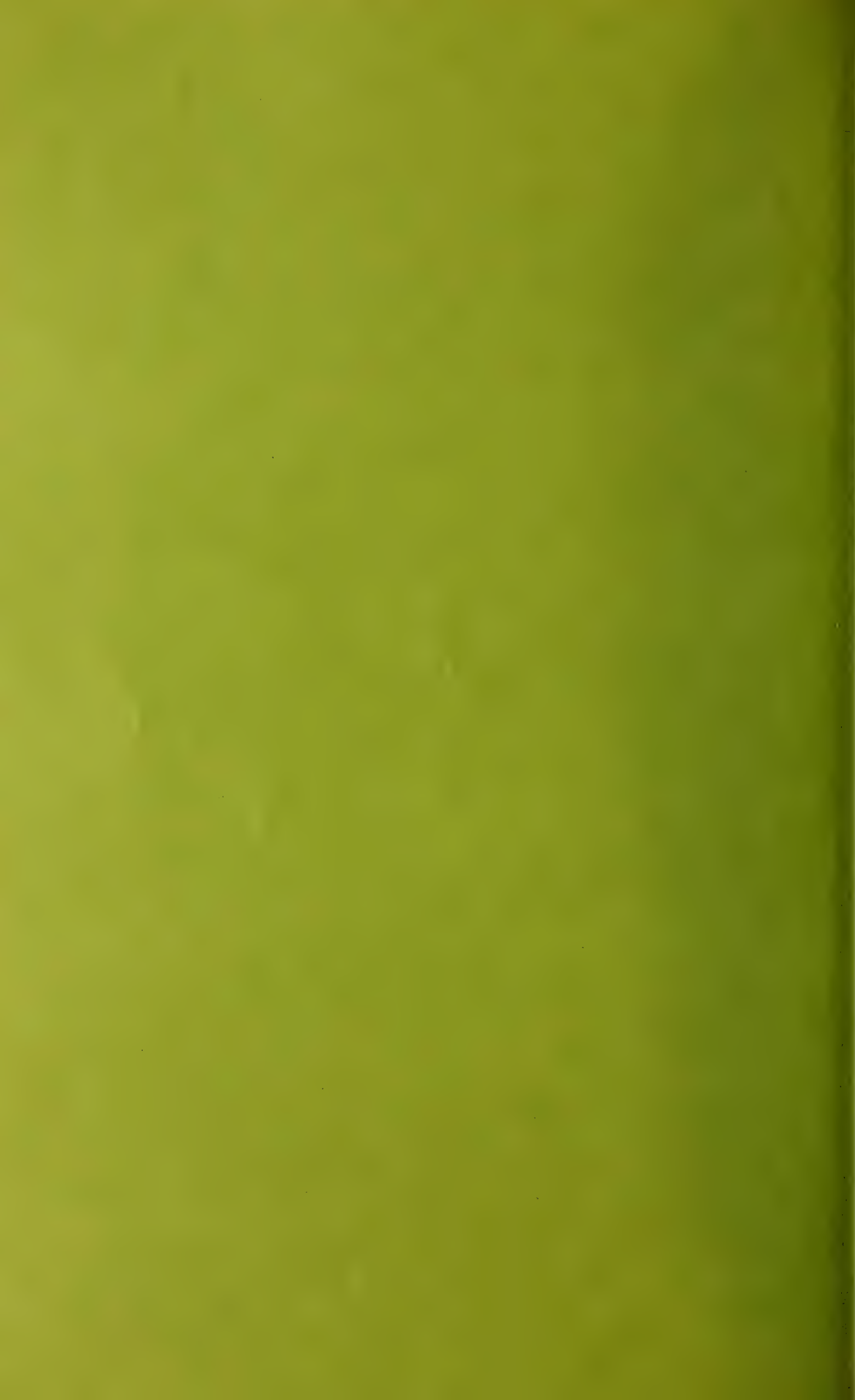
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PEST-MANAGEMENT CONCEPTS AND CONTROL OF TICK PARALYSIS IN BRITISH COLUMBIA

P. R. WILKINSON¹

ABSTRACT

Actual and potential methods for controlling and reducing paralysis of livestock and humans by the tick *Dermacentor andersoni* Stiles are analyzed, and assigned tentative "Geier ratings" of cost and effectiveness. Four broad categories of control are discussed: protection from toxins, prevention of engorgement, avoidance, and reduction in numbers of ticks.

Some control methods are undesirable because of their effects on the eco-system, including game animals. More information is needed on immunology of mammals to tick toxins and tick feeding, on variations and genetics of paralyzing ability in ticks, on range management in relation to paralysis, on the effects of herbicides on rodents and ticks, and on life-table parameters of ticks and rodents.

Introduction

Recent thinking on pest-management considers not only pests which affect man's use of some resource but the entire eco-system in which the pests occur (Clarke *et al*, 1967). This raises questions whether man, or some section of society, is utilizing the resource in the best way, taking into account economic, aesthetic and other aspects. Complex problems of desirable aims and means have arisen, for instance, in managing "wilderness" parks, in the relation of sport fishing in New Brunswick to DDT spraying of pulpwood forests, and in the siting of airfields in or near favourite bird haunts. This paper reviews present and potential methods of control of tick paralysis in British Columbia from the point of view of effectiveness, costs, and resource management. Such broad reviews of narrow fields are published too rarely, but are necessary to indicate priorities in pest control, and to enlist the interest of workers in related fields of enquiry. The pest-management concept emphasizes selectiveness in control, and fitting control methods to the biology of the noxious species (Geier, 1966).

The Problem

Classical tick paralysis in British Columbia is caused by *Dermacentor andersoni* Stiles. Rich (1957) described cases of toxicosis of cattle caused by *Otobius megnini*, but these are dis-

tinct from the ascending paralysis due to *D. andersoni*, described by Gregson (1962) and others.

Tick paralysis of cattle is of major concern in many parts of the cattle ranching area, even though large outbreaks are less common than formerly (Gregson, 1966), doubtless due to the widespread adoption of annual back-line spraying with BHC. The numbers of sheep in tick areas are declining, horses are rarely paralysed, and dogs usually recover because the owner removes the ticks, so that cattle are the most important species of livestock at risk. A few cases of human paralysis are reported each year to the Kamloops laboratory (Jellison & Gregson, 1950), and probably at least an equal number are not reported. Human fatalities, usually due to delay in removing the tick, still occur despite extensive publicity on the need for protective clothing and prompt removal of the ticks. Jellison and Gregson (1950) pointed out that girl children are more likely to be paralysed than boys because long hair tends to make a tick on the nape of the neck inconspicuous. Children on Indian reserves may tend to come in contact with tick foci more often than others, and records are now being kept to see whether these children provide a disproportionate number of paralysis cases.

Control Methods

Early hopes for control of *Dermacentor* ticks by Chalcid wasps were not fulfilled (Cooley and Kohls, 1934).

¹ Canada Department of Agriculture, Research Station, Entomology Section, P.O. Box 210, Kamloops, B.C.

Control measures recommended by entomologists [e.g. Hearle (1938), Neilson, Rich and Procter (1966), Neilson and Gregson (1967)] in British Columbia have been largely confined to reducing rodents, protecting cattle with acaricides, and protective clothing and de-ticking for humans. In contrast, in Australia, investigations by veterinarian Clunies-Ross and the Commonwealth serum laboratories, were directed towards curative measures applied to the paralysed mammal and in particular to the development of hyper-immune sera (Seddon, 1951).

The basic problem of *D. andersoni* on cattle in British Columbia is preventing paralysis. The main tick season, from late March to early May, is quite brief in the cattle areas and there is little indication that ticks are ever present in sufficient numbers to cause irreversible weight losses or other damage in the cattle.

Prevention of tick paralysis in cattle can be considered under four major headings.

A. Protecting susceptible animals from effects of toxins, needing no reduction in numbers of ticks engorging on the cattle.

B. Preventing ticks feeding to the stage of engorgement which is necessary to cause paralysis, with no attempt to reduce the numbers of ticks encountered by the cattle.

C. Reducing the numbers of ticks encountered by the cattle, but not reducing the numbers present on cattle ranges in general.

D. Reducing the number of ticks on cattle range, or in the entire range of the "paralysis strain" of *D. andersoni*. (Prairie strains rarely if ever cause cattle paralysis—Wilkinson and Lawson, 1965.)

Various techniques grouped under these headings, with selected references in the literature and brief remarks, are shown in Table 1. The Geier ratings are for satisfactoriness of treatment based on the diagram in Clark *et al* (1967), which rates treatments for excellence along scales for

"long-term reliability of protection," and "required frequency and intensity of human intervention." The ratings are provisional because many of these measures have never been given long term full-scale trial. The monetary cost of most of the measures is unknown. Insecticide for the BHC spray of cattle, B(4) (a) costs only about 65c per animal per year.

Only items under sections A(2), A(3), A(4) and D would be applicable to reduction of tick paralysis of humans. Items under Section D would acquire added importance if tick-borne diseases in Canada (Gregson, 1964), become more virulent or new diseases are introduced, or if tick vectors interfere with eradication or serum-testing of brucellosis of cattle (Volkova *et al*, 1960).

Long term investigations under B (1) should be started to see whether an inheritable resistance to ticks or tick paralysis can be detected in a variety of breeds of cattle, and developed by selection. The high Geier rating compensates for the inherent difficulties in investigating and applying this method. The reasons for lack of paralysis in wild ungulates are obscure (Wilkinson, 1965).

For successful investigation of control measures under D (1), D (2) and D (3), much more knowledge is needed on the host-potential (Milne, 1949), of the several species of wild animals inhabiting tick foci in the spring range of cattle. The main methods proposed at present involve capture-mark-release studies on rodent and other hosts, to provide data for life-tables of tick populations on selected study areas. Preliminary experiments, and theoretical considerations of sampling populations of such a polyphagous tick and its mobile hosts, indicate that the compilation of useful life-tables will be very difficult even with much more massively supported efforts than are likely to be available. Nevertheless, by applying crude approximations, in the belief that some data are better than none, it should be possible to improve our

TABLE 1—Status of knowledge on methods for control of tick paralysis of cattle in British Columbia.

METHOD	Not Investigated or no publications known	Related problem investigated	Investigations in progress, at Kamloops		REMARKS
			1—Introductory A—Advanced	Probable Geier rating*	
A. Protection of susceptible animals from paralysis					
(1) Immunization against paralysis, e.g. by serum from hyper-immune host		Seddon (1951)		B3	Hyper-immune serum gives 14 day protection of dogs from <i>Ixodes holocyclus</i> in Australia.
(2) Cure of paralysis by hyper-immune serum		Seddon (1951)		C2/C3	This author discusses curative action of hyper-immune serum for dogs paralysed by <i>Ixodes holocyclus</i> .
(3) Chemical antidotes	+			C2/C3	This and the preceding method would be dependent on finding the paralysed cattle and administering the antidote or serum before death occurs. Toxin has not yet been isolated or identified.
(4) Replacement of paralyzing strain of <i>D. andersoni</i> by non-paralyzing strain, by distribution of non-paralysing males	+			B2	Paralysis by <i>D. andersoni</i> is confined to the northwestern portion of its distribution (Jellison & Gregson, 1950).
B. Prevention of engorgement of ticks, after crawling on cattle					
(1) Breed resistance		Riek (1962) Wilkinson (1962)		A1 or A2	A long term solution. Conservative approach in accepting only a few cattle breeds (e.g. Hereford), is lessening, but willingness to include resistance to tick paralysis in a selective breeding program is doubtful.
(2) Age resistance			I	B2	Apparent greater susceptibility of yearling cattle compared with cows, calves and two year olds, needs scientific investigation. Exclusion of susceptible age groups from heavily infested areas may be practicable, on some properties.
(3) Induced resistance		Riek (1958)		B2	In deer there is a possibility that prior infestations with <i>D. albipictus</i> reduce susceptibility either to <i>D. andersoni</i> infestation or to paralysis (Wilkinson, 1965).
(a) from antigen of same species			I	B2	
(b) from antigen of other tick species					

(4) Insecticides on cattle (a) Sprays, etc.	A	A3	Unusually concentrated (0.25% BHC) spray on back lines is highly effective [Neilson, Rich & Procter (1966)]. BHC residues in cattle need re-examination (Rich, unpublished). Possibility of resistant strains of ticks developing.
(b) Systemics		B3	Further investigations are needed in translocation of systemic insecticides applied as sprays, pour-on, and in feed. May have short residual periods.
(c) Repellent or other compound interfering with engorgement behavior, with 7-14 day residual period		B3	
C. Cattle prevented from encountering ticks			
(1) Fall grazing of infested fields or relatively small "tick foci," instead of spring grazing		A2	Yield of forage may be nearly as great, and the practice would probably be beneficial to bunch grass (<i>Agropyron spicatum</i>). Some rearrangement of fencing may be necessary, and water may be a problem.
(2) Only less active groups of cattle, e.g. cows and calves graze tick areas		B2 or A2	This appears to account for lack of paralysis in some areas with tick infested hillslides. No close investigation has been made.
D. Reductions of total number of ticks on cattle range			
(1) Vegetation modification	A	A2 or B2	Hypothesis of independence rejected ($P=0.001$), i.e. implication of association with shrubs, in one field in Kamloops area (Wilkinson, 1967). Qualitatively appears to be generally applicable to the shrub species mentioned. Due to forestry regulations and nature of tick foci, prospects for use of controlled fires are poor. Herbicide trials are in progress.
(2) Reduction of wild hosts (a) hosts of immature stage, mainly rodents		B2	Parker stated that destruction of Columbian ground squirrels, along with other measures, was locally and partially successful in reducing <i>D. andersoni</i> numbers in the Bitter-root Valley. No controlled experiments were mentioned.
(b) hosts of all stages, and host of adult stage	I	C3	Shilova is more optimistic concerning control of <i>Ixodes persulcatus</i> by aerial and manual applications of poison baits. Untreated susceptible cattle are probably more favourable hosts than wild large animals (deer, coyotes), and probably could substitute for porcupines.

Drummond & Graham (1964)

Parker (1933)
Shilova et al (1967)

(3) Reduction of ticks on rodents (a) Burrow dusting and rodent dusting		Kartman (1958)	B2	Kartman's paper refers to control of fleas on <i>Microtus</i> and other rodents by using DDT in bait boxes. Possible danger of pesticides accumulating in or sterilizing desirable predators, through the food chain, if chlorinated hydrocarbons used.
(b) Baits for rodents with systemic action on ticks		Shilova et al (1967)	B2	Promising trials of rodent baits, combined with systemic acaricides, against <i>Ixodes</i> ticks. No information on effects on predators.
(4) Dusting of large areas with acaricides		Uspensky (1967)	B2	50 kg of 10% DDT dust/hectare against <i>Ixodes</i> . Same comments on residues as 3(a). Also possible damage to sport fisheries.
(5) Reduction of free living ticks as a by-product of cattle-spraying			A2	This effect could change Geier rating of B. 4(a) from A3 to A2 and could be used to reduce risk to human population, by grazing treated cattle in the problem area.
(6) Artificial induction of diapause			I	Some authors (Barker et al 1964), have suggested that diapause might be prevented in "long-day" insects by a single flash effectively extending day-length. This might also conceivably be used to force "short-day" ticks into diapause, over limited areas.
(7) Liberation of effectively sterilized males			B2	Irradiation of large numbers of male ticks technically feasible, but males can, and females appear to, mate more than once (Gregson unpublished).
(a) Irradiated males			I	No genetic incompatibilities have yet been recorded. Subsequent matings with normal males may downgrade this to C2 Geier rating.
(b) Males with genetic incompatibility	+		I	

* In accordance with the general practice of excellence culminating with A1, Geier's categories (Clark et al 1967) have been recoded as Protection: A=High, B=Satisfactory, C=Limited.
Intervention required (after method well established): 1=Minimal, 2=Less than annual, 3=Annual or more frequent.

knowledge of the major hosts that maintain tick populations on cattle range. Using this knowledge, it may be possible to modify the environment so that it becomes unfavourable to ticks; this may well be economically worthwhile, for instance, on selected areas of cattle range, around settlements where children wander, and on camp grounds. The great majority of tick paralysis cases in British Columbia are due to ticks picked up in montane forest or in tick foci in grasslands (Wilkinson, 1967).

Massive and widespread applications of DDT, such as 5 kg/hectare, Table 1 D (4), may be undesirable because of concentration in wildlife food chains, storage in soil, and danger to fish. Such treatments have been considered justifiable in the U.S.S.R. to protect humans from encephalitis carried mainly by *Ixodes* ticks. Uspensky (1967), mentioned an annual application of 10⁷ kg of 10% DDT dust over 200,000 hectares. However, Uspensky implies that more economical methods should be found, and that the incidence of encephalitis has not been reduced as much as expected.

Much of the spring range of cattle is used by deer and gamebirds. These are a valuable source of meat and recreation and of income to sellers of supplies and services to hunters; moreover wild animals have an aesthetic value to an even wider circle of people. Widespread destruction of shrubs D (1) would be inadvisable because these shrubs (Wilkinson, 1967), are valuable as the main winter browse species for deer, and may be of importance to grouse. Preliminary experiments have been in progress at Kamloops since 1965 to discover if destruction of shrubs is an effective

and economically feasible method of reducing ticks in small tick foci within large relatively uninfested areas of grassland, or around settlements and campsites.

Discussion

The work of Clark *et al* (1967) and Beirne (1967), should encourage applied biologists to re-examine pest organisms against the background of the eco-system and with optimum use of resources in mind. Often they will be hampered by a lack of definition of the objectives in resource utilization, because conflicts of interest between different sections of the community are likely to continue for some time.

Detailed analysis of any insect control problem will probably reveal important gaps in our knowledge, as in Table 1. The study of these basic problems closely related to potential control measures seems particularly appropriate to government laboratories, since pursuit of abstract knowledge can best be left to universities, aided by relatively short term studies by students. Detailed work on well known methods, such as studies of dosage and methods of application of pesticides under local conditions, is appropriate to those close to the extension field.

This analysis of the problem of tick paralysis shows the extent of the specialties involved, ranging from mammalian immunology, through insecticide toxicology and tick ecology, to range ecology and agronomy. A balanced effort of wide coverage is needed, scaled to the importance of the problem, to identify and pursue the most profitable lines of investigation and control.

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WOOD- AND BARK-FEEDING COLEOPTERA OF FELLED SPRUCE IN INTERIOR BRITISH COLUMBIA

D. A. Ross¹

ABSTRACT

A list of wood- and bark-feeding Coleoptera of interior British Columbia reared from *Picea glauca* (Moench) Voss and *P. engelmanni* Parry in 1928-30 and 1965-67, and the range of their emergence dates at Trinity Valley and Vernon, B.C., respectively, are presented. The species of economic importance reared in significant numbers were the wood borers *Tetropium cinnamopterum* Kirby, *Serropalpus substriatus* Hald., and *Monochamus oregonensis* LeConte, and the bark beetle *Dendroctonus obesus* (Mannerheim).

Wood- and bark-feeding beetles cause significant losses in British Columbia's forests each year. A knowledge of the species involved and their times of emergence and attack are requisite to the intelligent management of our forests.

Two sources of data on wood- and bark-feeding Coleoptera from felled spruce in interior British Columbia are considered here. The first is unpublished information gathered by J. R. L. Howell and others² in 1928-30, and the second by members of the Forest Insect and Disease Survey during 1965-67.

Howell reared insects from two felled Engelmann spruce trees at Trinity Valley, B.C., to ascertain the species complex of the stump, bole and limbs. One tree, 9 inches d.b.h. and 85 feet tall, was blown down early in the summer of 1927. The other tree, of unrecorded dimensions, was presumed to have blown down in the spring of 1929. In each case the material was caged early in the spring within a year of blowdown.

In 1965, the author began investigations to determine the species of wood-infesting Coleoptera of economic importance to spruce in the Interior. Engelmann and white spruce trees windblown or logged in 1964, or felled in 1965 and 1966 by Survey personnel in a number of localities were

left exposed to attack for the summer. Samples from a total of 25 infested logs were taken to Vernon from Ashcroft, Lumby, Cherryville, Waitabit Creek, and other localities in the southern Interior, and from points northward into Pine Pass to Mile 485 on the Alaska Highway in northern British Columbia. Each sample consisted of three 2-foot-long bole sections 8 to 12 inches in diameter. In the fall the boles were caged outdoors at Vernon and emergents were collected during 1965-1967.

Howell reared 11 wood- and bark-feeding species of Coleoptera from the stumps, 20 from the boles and five from the limbs of the two trees (Table 1). *Monochamus notatus* (Drury), was the only wood-boring species reared in significant numbers from the bole: all adults of this species emerged the second year after the attack. *Polygraphus rufipennis* (Kirby), a bark feeder, occurred abundantly in the bole and to a much lesser degree in the limbs and stump. *Dryocoetes affaber* (Mannerheim), was the only other species of bark beetle present in significant numbers; it was confined to the bole.

The only species of Coleoptera present in large numbers and reared from a significant proportion of the samples of white and Engelmann spruce (Table 2) were: the wood borers *Tetropium cinnamopterum*, *Serropalpus substriatus*, and *Monochamus oregonensis*; the snout beetle, *Pissodes alascensis* Hopkins, and the bark beetle *Dendroctonus obesus*.

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² In files of Forest Entomology Laboratory, Vernon, B.C.

TABLE 1—Emergence of wood- and bark-feeding insects the first and second summer following caging,¹ of Engelmann spruce wind-felled in 1927 and 1929, Trinity Valley, B.C.

Species	Stump	No. emergents ² ex.		Limbs	Emergence range
		Bole			
CERAMBYCIDAE					
Acmaeops sp.	1				Aug. 8
Anthophilax mirificus Bland		2			May 16 - May 28
Leptura obliterata Hald.	3(1)	1			Aug. 12 - Aug. 14
Megasemum asperum (LeC.)	1				Aug. 10
Monochamus notatus (Drury)		(28)			June 22 - Aug. 6
Monochamus oregonensis (LeC.)		3(1)			June 16 - Aug. 21
Neacanthocinus obliquus (LeC.)		2	1		July 25
Phymatodes densipennis Csy.	1(1)	3(2)			May 28 - July 6
Pogonocherus propinquus Fall		(1)			Aug. 7
Rhagium lineatum (Oliv.)	5	3			May 14 - June 20
Tetropium velutinum LeC.	1(1)	5(1)	1		May 26 - Aug. 7
Xylita laevigata (Hellw.)	2	10(1)	2		May 15 - July 30
Xylotrechus undulatus (Say)		1			Aug. 1
BUPRESTIDAE					
Buprestis adjecta (LeC.)		(1)			July 18
MELANDRYIDAE					
Scotochroa basalis LeC.	(1)	1(1)			July 13 - Aug. 10
Serropalpus substriatus Hald.		2			July 14 - July 24
CURCULIONIDAE					
Pissodes alascensis Hopk.		6	3		May 26 - Sep. 11
Pissodes schwartzii Hopk.		4			June 5
SCOLYTIDAE					
Dendroctonus obesus (Mann.)	4	12(1)			May 12 - Aug. 7
Dryocoetes septentrionus (Mann.)	7(7)	2			June 3 - June 24
Polygraphus rufipennis (Kby.)	23(1)	5960(168)	95(8)		May 16 - Sep. 25
Dryocoetes affaber (Mann.)		79(59)			June 26 - Aug. 16

¹ Caged the spring following blowdown.² Number of second year emergents in brackets.

Of these only the three species of wood borers and the bark beetle *D. obesus* are of economic importance. The wood borers make holes in the wood reducing the quality of the lumber, and the bark beetles may cause deterioration of the wood by introduc-

ing blue staining fungi.

The range of emergence dates noted in Table 2 serves only as a rough guide since the logs were infested in several localities at various times of the year and then were reared at Vernon.

TABLE 2—Emergence at Vernon in 1965-67 from 25 samples of Engelmann and white spruce logs from Interior British Columbia.

Species	No. samples infested	Range in no. emergents	Range of emergence dates
CERAMBYCIDAE			
<i>Atimia dorsalis</i> LeC.	1	1	July 26
<i>Meriellum proteus</i> Kby.	1	2	June 28 - July 2
<i>Monochamus oregonensis</i> LeC.	5	2-23	May 27 - July 16
<i>Neoclytus muricatus</i> Kby.	3	1-14	June 13 - Aug. 1
<i>Megasemum asperum</i> (LeC.)	3	1	? - Aug. 2
<i>Tetropium cinnamopterum</i> LeC.	7	6-95	May 5 - June 26
<i>Xylotrechus undulatus</i> Say	1	1	July 13
MELANDRYIDAE			
<i>Serropalpus substriatus</i> Hald.	7	2-88	June 13 - Aug. 4
BUPRESTIDAE			
<i>Melanophila drummondi</i> Kby.	4	2- 9	May 4 - July 27
CURCULIONIDAE			
<i>Pissodes alascensis</i> Hopk.	4	8-43	June 19 - Aug. 10
SCOLYTIDAE			
<i>Dendroctonus obesus</i> (Mann.)	6	1-75	May 2 - Aug. 13
<i>Dryocoetes septentrionis</i> (Mann.)	2	8-39	July 4 - July 25
<i>Polygraphus rufipennis</i> Kby.	3	12-58	May 2 - July 24
SIRICIDAE [†]	8	1-30	July 5 - Aug. 14

[†] Horntails—recorded to indicate relative importance.

A RECORD OF *MEGACHILE ROTUNDATA* (F.) FROM ASHCROFT, BRITISH COLUMBIA

J. C. ARRAND AND J. CORNER

The leaf-cutter bee, *Megachile rotundata* (F.) is a Eurasian species believed to have been introduced to North America on several occasions. It was recorded in Virginia in 1937, and since then has been recorded from Kansas, Missouri, Texas, California, Utah, Idaho, Nevada, Oregon, and Washington (Stephen, 1962).

In 1963 specimens of *Megachile rotundata* (F.) were noted in a collection of bees from Ashcroft. Identifica-

tion was confirmed by W. P. Stephen, Oregon State University, Corvallis, Oregon. This is believed to be the first record of *M. rotundata* occurring naturally in Canada. Since 1963 large numbers of this species have been brought in from Oregon, to Ashcroft and Kamloops in the interior of British Columbia, for alfalfa pollination. Some bees have escaped and nested in cracks or under shingles in buildings nearby. Prepupae have survived the past three winters in these locations.

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FIRST OCCURRENCE OF BALSAM WOOLLY APHID IN THE INTERIOR OF BRITISH COLUMBIA

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ABSTRACT

The balsam woolly aphid, *Adelges piceae* (Ratzeburg), was discovered near Vancouver in 1958, and in the interior of British Columbia in 1967. Infested planted ornamentals were found at two locations in the Okanagan Valley: three *Abies alba* Miller near Oliver and two *Abies concolor* (Gordon and Glendenning) in Penticton. These trees were either burned or sprayed. No aphids were found on native alpine fir, *Abies lasiocarpa* (Hooker).

The balsam woolly aphid, *Adelges piceae* (Ratz.), is an important pest of true firs, *Abies* spp. This native of Europe, found in North America in 1908, now occurs from the Maritime Provinces of Canada south to North Carolina and from southern British Columbia to California. Since its discovery near Vancouver in 1958, it has become firmly established in that area on the mainland and on southern Vancouver Island.

On 28 April 1967, infested bark and branch samples from three planted ornamental silver firs, *Abies alba* Mill., near Oliver in the Okanagan Valley were submitted by the owner. Additional samples taken on 15 May contained a maximum of 1,890 eggs and 45 crawlers per square-inch bark sample, and 33 crawlers per 24-inch branch.

The trees appeared vigorous in spite of the heavy stem attack. They were imported from Holland and planted at the Oliver site in 1928. They were infested either when planted and the aphids had persisted on them for 29 years, or infestation occurred at a later date, possibly from exposure to infested transplanted stock.

At the request of the B.C. Forest Service, the trees were sprayed by a pest control firm on 16 May. Wettable powder formulations of Tedion, Sevin and Thiodan were mixed at concentrations of 1 lb. each to 90 gal of water and applied at the rate of 30 gal per tree. Bark and branch samples from the sprayed trees were

examined in June; only one living aphid was found. Although the spray was almost 100% effective, it was decided to destroy all three trees and they were subsequently felled and burned.

The discovery of the balsam woolly aphid at Oliver resulted in a special survey of ornamental firs from the United States border to Penticton. The survey was conducted between 23 May and 13 August by B.C. Forest Service crews supervised by members of the Forest Insect and Disease Survey. About 1,100 ornamental fir trees were examined, resulting in the discovery of two infested white firs, *Abies concolor* (Gord. and Glend.), in Penticton. These trees were about 40 ft high and had a light population of aphids on the branches. The origin and date of transplanting of the trees were not known.

The trees were sprayed with a mixture of Thiodan and Sevin (1 lb. W.P. of each per 100 gal of water), applied at the rate of 70 gal per tree. Control was satisfactory as later sampling showed no living aphids.

All infested ornamental fir trees were less than 15 miles from stands of highly susceptible native alpine fir, *Abies lasiocarpa* (Hook.), a distance suspected to be within the airborne dispersal limits of the insect. However, aerial and ground surveys of these stands in July and August failed to produce evidence of the balsam woolly aphid. The native, non-destructive adelgid, *Pineus abietinus* Underwood and Balch, was common.

The balsam woolly aphid presum-

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ably was introduced into southwestern British Columbia on nursery stock imported from infested areas. In the Interior it apparently had a similar introduction. Steps taken to prevent further spread included a voluntary industry quarantine on the movement of *Abies* spp. logs outside of the infested areas, and federal and provincial quarantines preventing the sale or movement of *Abies* nursery stock into or within the Province. This action

should reduce the long-range spread of the aphid, leaving only natural spread by wind and possibly birds to contend with. Surveys to detect spread on ornamentals in other interior areas prior to the present legislation are necessary. Spraying or felling of such trees is recommended; if spread into natural stands far removed from the existing major infestation is detected, similar direct control measures may be advisable.

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PROTECTING LARCH LOGS FROM *TETROPIUM VELUTINUM* LECONTE WITH LINDANE EMULSION

D. A. ROSS AND N. J. GEISTLINGER¹

ABSTRACT

At Trinity Valley, British Columbia, a 1% emulsion of lindane applied on 12 June 1967, protected freshly felled *Larix occidentalis* Nuttall from attack by *Tetropium velutinum* LeConte. The same concentration, applied to infested logs on 14 August reduced damage but was too late to satisfactorily prevent larval penetration of the wood.

Introduction

Ross (1967) noted the importance of the western larch borer, *Tetropium velutinum* LeConte, as a wood borer in logs of western larch, *Larix occidentalis* Nuttall. As with *Monochamus*, injury by *Tetropium* may be prevented by removing recently dead trees or logs from the forest before the beetles oviposit, or by utilizing timber before larvae in the bark enter the wood. Various authors including Becker (1959), and Ross and Downton (1966), have shown that lindane emulsion protects logs from wood-borer attack, although its effectiveness had not been tried specifically against *Tetropium*. In 1967 the spray was used A to prevent oviposition by *Tetropium velutinum* and B to reduce damage of the wood by larvae.

Methods

Three 14-inch d.b.h. western larch at Trinity Valley were felled on 12 June 1967, and cut into 30 logs, each 4 feet long. Ten randomly selected logs for Treatment A were placed in the forest about 100 feet from the remaining 20.

Treatment A. On 12 June a 1% lindane emulsion² was applied with a hand sprayer to the point of runoff on all sides of each log in the group of 10.

Treatment B. On 14 August every second remaining log was removed 100 feet and sprayed with 1% lindane. The remaining 10 logs served as controls. By this time, numerous larvae had penetrated the wood.

In both treatments and in the control, individual logs were spaced 10 feet apart parallel to an east-west line.

Foot-long sections of the treated and control logs were peeled in mid-October 1967, and the numbers of

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² Lindane powder mixed with xylol and an emulsifier in water.

Tetropium larval entrance holes, and the living and dead larvae under the bark were counted.

Results

Table 1 shows the average and range in numbers of *Tetropium velutinum* larval entrance holes in treated and control larch logs in October, 1967.

Woodpeckers had drilled holes into, and scaled bark off most of the logs given Treatment B or no treatment. Forty-five per cent of the 197 *Tetropium* larvae that were under the bark but had not penetrated the wood of the logs of Treatment B were dead: 20% of the 98 larvae under the bark of the control logs were dead.

TABLE 1—Influence of Treatment on Western Larch Borers in Larch Logs.

Treatment and Date 1967	No. <i>Tetropium</i> entrance holes per sq ft	
	Average	Range
A. Lindane 1%—June 12	0	—
B. Lindane 1%—Aug. 14	4.5	3.0-10.9
Control	8.4	5.3-12.3

Discussion

The absence of living or dead *Tetropium* larvae, the absence of galleries in the wood, and the presence of larvae in the control logs indicate the effectiveness of Treatment A in preventing damage to western larch logs.

Treatment B was applied too late to prevent damage by some larvae, but did reduce overall damage.

The presence of a larger number of larvae under the bark of logs treated on 14 August than in the control logs may have been the result of selectivity by woodpeckers. However, it was more likely due to the effect of the poison which probably killed or weakened some larvae that otherwise would have penetrated the wood.

There was a greater proportion of

dead *Tetropium* larvae under the bark of logs receiving Treatment B (45% mortality) than in the control logs (20% mortality), indicating that the poison had killed some of the larvae under the bark. Unfortunately woodpeckers had removed many larvae from the infested logs making data on living and dead *Tetropium* inconclusive.

There were no bark beetles, Scolytidae, in any of the samples receiving Treatment B, as there were in a similar trial to control *Monochamus* in pine (Ross and Downton, 1966). Bark beetle galleries in some instances would presumably have permitted better penetration of the poison into the bark.

Acknowledgements

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THRIPS INFESTING THE TIPS OF ASPARAGUS SPEARS¹F. L. BANHAM¹

ABSTRACT

The onion thrips, *Thrips tabaci* Lind., and the flower thrips, *Frankliniella tritici* (Fitch), mainly from *varicornis* Bagnall, were found in the tips of asparagus spears from commercial fields in the southern interior of British Columbia. Both species occurred in about equal numbers except in one area, where *F. tritici* form *varicornis* was the more abundant species. Only adults were found. These migrant thrips do not damage the spears but are a potential source of contamination in the processed product. Thrips were most abundant in spears with loose or "blown" tips. In all areas, the highest infestations of thrips in the spears occurred in fields with a heavy weed cover. The weed cover and bordering forage crops, including alfalfa, provided a constant source of infestation. Increased numbers of thrips in spears coincided with increased daily temperatures and cutting of bordering forage crops. Effective weed control reduced the numbers of thrips infesting the spears.

Introduction

The presence of thrips in the tips of harvested asparagus spears has caused concern among growers and processors in the southern interior of British Columbia since 1961. When thrips are abundant in the tips of asparagus spears, processors are forced to use special washing processes prior to canning or freezing to remove this potential source of contamination from the processed product. In some instances, processors have threatened to cancel the contracts of growers whose asparagus was heavily infested with thrips. Field and laboratory investigations were conducted to determine the extent of feeding damage, the species, the stage of insect development, the probable sources of infestation, and an economic control against thrips infesting growing asparagus spears.

Materials and Methods

In 1963 and 1964, the occurrence of thrips in asparagus fields was determined in four widely separated areas from Kamloops to Kelowna. In one area, which was heavily infested, five fields were inspected at weekly intervals throughout the harvesting seasons. In three other areas, inspections were made in fewer fields and less frequently. Field inspections were made by dislodging thrips from four

or more samples each of twenty-five growing or freshly harvested spears. Thrips were dislodged from the spears by tapping individual spears into the palm of the hand. Spears were tapped over a sheet of white paper when excessive amounts of soil particles or other debris made sorting of the thrips difficult.

In 1964, weekly laboratory examinations were made to determine the numbers of thrips, stage of development, and the extent of feeding damage on the spears and bracts. Four samples, each of ten randomly selected asparagus spears, were harvested from fields infested with thrips. One sample was stored in a potassium cyanide killing bottle and the other three sealed in plastic bags. Asparagus spears from the killing bottles were dissected with the aid of a binocular microscope to determine the numbers of thrips, their stage of development, the location, and extent of feeding damage. Bracts were removed from spears stored in the plastic bags. Immediately, each was placed in a 10% sodium chloride brine solution and agitated. Flotation debris was inspected under the microscope to determine the presence of thrips or parts of thrips.

To ascertain the effect of weed control on infestations of thrips in the asparagus spears, weekly counts were continued in 1964 in two fields which, in 1963, had a dense weed growth and

¹ Contribution No. 237. Research Station, Canada Agriculture Summerland, British Columbia.

were heavily infested with thrips. In one field, a pre-emergence application of Monuron herbicide was made in April, 1964. In the second, a heavy weed cover was suppressed by disc-cultivation in the first week of June. The abundance of thrips on the foliage of weed plants in the asparagus fields and on adjacent crop plants was determined at the same intervals by sweeping with a 13-inch diameter canvas sweep net.

Results

Two species of thrips were identified by Dr. W. R. Richards, Systematics Unit, Entomology Research Institute, Canada Agriculture, Ottawa, in samples collected from asparagus spears, weed plants and adjacent forage and crop plants. Only adults were found in the tips of the asparagus spears. The onion thrips, *Thrips tabaci* Lind., and the flower thrips, *Frankliniella tritici* (Fitch), mainly form *varicornis* Bagnall, were present in about equal numbers both mid-way through and at the end of the harvesting season in all but one area where the latter was the more abundant species throughout the season. In all areas, fields with a heavy weed cover including: Canada thistle, *Cirsium arvense* (L.) Scop.; common dandelion, *Taraxacum officinale* Weber; shepherd's purse, *Capsella bursa-pastoris* (L.) Medic.; lamb's quarters, *Chenopodium album* L.; couch grass *Agropyron repens* (L.) Beauv.; and storksbill, *Erodium cicutarium* L.; were infested with several forms of *F. tritici*. Some *T. tabaci* were also present. *F. tritici* form *varicornis* was taken on wheat and was also more abundant than *T. tabaci* on alfalfa. Nymphs and adult thrips were collected from most of these plant species.

Laboratory examinations showed that thrips were present only on the bracts of the tips of the asparagus spears. Most thrips were found in spears with loose bracts. These spears are described as having open or "blown" tips. Thrips observed feeding or harbouring on the bracts caused no

detectable damage.

The highest infestations of thrips occurred in the Armstrong area in asparagus fields with heavy weed cover. In 1963, counts averaged 13.3 thrips per spear (range 0-19) in one weedy field compared to 0.5 thrips per spear (range 0-3) in a clean cultivated field. In the other areas, counts during the same period varied from 0.02 to 1.4 thrips per spear (range 0 to 3). Armstrong was the only area where populations of thrips in the weed cover of asparagus fields were higher than those in the bordering weed or crop cover.

At Armstrong, when infestations of thrips in the asparagus spears were high, mature alfalfa bordering the fields had populations averaging 10.9 thrips per sweep and fall wheat 1.9 thrips per sweep. Lamb's quarters in or bordering the field averaged 8.5 thrips per sweep and shepherd's purse 2.1 per sweep. Moderate to heavy foliage covers of Canada thistle, common dandelion and storksbill had lighter populations. Couch grass had the lowest populations.

In 1963 and 1964, populations of thrips in the asparagus fields and adjacent vegetation increased as the season progressed. Populations of thrips increased significantly in the third and fourth weeks of May and continued to increase till the third week of June when harvesting ended. In all areas, the initial increase in populations of thrips coincided with the cutting and drying of forage crops in nearby fields. This is illustrated by brine flotation counts which rose to 7.0 thrips per spear two days after and peaked at 10.3 thrips per spear nine days after the adjacent field of alfalfa was cut. The pre-cut count averaged only 0.75 thrips per spear.

Suppressing or eradicating the weed cover within an asparagus field reduced the numbers of thrips in the spears. At Armstrong, in 1964 a pre-emergence application of Monuron herbicide effectively suppressed the growth of weeds in one field which had a heavy weed growth in 1963. In

the second week of June, the average number of thrips in the asparagus spears was 0.3 per spear in 1964 compared with 4.1 per spear in 1963. The 1964 count was lower than the 0.5 thrips per spear average for clean cultivated fields in the Armstrong area and was similar to that of clean cultivated fields in other areas. During the harvesting season, disc-cultivation to suppress a heavy cover of weeds also reduced infestations of thrips in the spears from 10.3 per spear to 3.8 per spear in one week and to 1.5 per spear in two weeks.

Discussion

Processors can tolerate the occasional presence of small numbers of thrips in the tips of a few asparagus spears. These can be removed from the bracts by washing prior to processing. Although *F. tritici* and *T. tabaci* cause no apparent damage to the asparagus, heavy infestations of 13 thrips per spear create a risk that the processed product will be contaminated.

In California, Michelbacher and Bacon (1949), reported that mainly adult thrips of the *Frankliniella* complex infested asparagus spears for periods of about one week in some years. Fields with heavy weed cover had the highest infestations. In British Columbia, only adult thrips were found, indicating that these were migrants. *F. tritici*, mainly form *varicornis*, and *T. tabaci* infested asparagus spears for about five weeks. The maximum number of thrips per spear was about double that reported from California.

Laboratory inspections made in 1962, at the processing plant of Cana-

dian Cannery Ltd., Vancouver, showed that the highest incidence of thrips occurred in asparagus spears from the Armstrong area. Field and laboratory investigations in 1963 and 1964 confirmed this. Field inspections showed that weed growth was heavier in the non-irrigated Armstrong area than it was in the irrigated areas. Growers in the Armstrong area claim a heavy weed cover shades the asparagus and slows "tip-blowing." Field observations showed this cultural practice increased the amount of "tip-blowing" by causing over-maturity; mature spears frequently were shielded from view during harvesting operations. "Blown" tips permitted *F. tritici* and *T. tabaci* to enter and feed or harbour on the bracts. In fields with a heavy weed cover, the chance of migrant thrips entering the bracts would be reduced by harvesting the spears at a less mature stage when the tips are tight.

Weed control in and bordering an asparagus field reduces infestations of thrips in the spears. The use of herbicides and cultivation to control the weeds lowered infestations of thrips to tolerable levels. Further reductions might be achieved by staggering the time of cutting forage in each bordering field. Trap strips of alfalfa or other forage left on the side of a field bordering the asparagus should assist further to reduce the number of thrips.

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INTEGRATED CONTROL OF THE FRUIT-TREE LEAF ROLLER, *ARCHIPS ARGYROSPILUS* (WALKER), AND THE EYE-SPOTTED BUD MOTH, *SPILONOTA OCELLANA* (DENIS & SCHIFFERMULLER)

HAROLD F. MADSEN¹ AND R. S. DOWNING¹

ABSTRACT

Pre-bloom sprays to control the fruit-tree leaf roller, *Archips argyropilus* (Walker), and the eye-spotted bud moth, *Spilonota ocellana* (Denis & Schiffermüller), were applied in an apple orchard where no insecticides have been used for 6 years. The phytophagous mites in the orchard are held under control by predacious phytoseiid mites.

Azinphos-methyl at 5 and 2½ lb. 25% W.P. per acre gave excellent control of the two insects when applied at the pre-pink stage. Dormant oil at 6 gal. per acre applied at the ½-inch green stage was ineffective. Oil at 6 gal. and azinphos-methyl at 2½ lb. did not reduce predacious phytoseiid mites over the untreated control. No phytoseiid mites were found on trees treated with azinphos-methyl at 5 lb. The timing of the effective sprays would not interfere with a program of codling moth control by the sterility method.

Introduction

Interest and research on control of the fruit-tree leaf roller, *Archips argyropilus* (Walker), and the eye-spotted bud moth, *Spilonota ocellana* (Denis & Schiffermüller), has declined in recent years following the introduction of wide spectrum insecticides for codling moth control. Materials such as azinphos-methyl and carbaryl in regularly applied seasonal spray programs on apples has reduced the fruit-tree leaf roller and eye-spotted bud moth to minor pests.

Developments in autocidal control of the codling moth (Proverbs, Newton and Logan, 1967), have raised the question whether these insects will become major pests if codling moth sprays are no longer required. The type of fruit damage caused by these two pests in British Columbia orchards has been described by Madsen and Arrand (1966). An indication that both the fruit-tree leaf roller and eye-spotted bud moth can increase to damaging numbers has been noted in an orchard which has not received codling moth sprays since 1961. In the above orchard, Downing and Moilliet (1967), have shown that both the European red mite, *Panony-*

chus ulmi (Koch), and the McDaniel mite, *Tetranychus mcdanieli* (McGregor), are held below economic levels in McIntosh and Spartan trees by the predacious phytoseiid mite, *Metaseiulus occidentalis* (Nesbitt).

Studies were begun in this experimental orchard in 1967 to develop an integrated control program for the fruit-tree leaf roller and the eye-spotted bud moth. The objective was to find a chemical control that would not upset natural control of phytophagous mites nor have an adverse effect on released codling moths sterilized by gamma radiation. Spray applications were limited to the pre-bloom period of tree growth. This timing was at least two weeks before a codling moth release program would begin, and at a time when some predacious mites were still in overwintering sites.

Methods

Treatments were applied to three apple varieties in the test orchard, Red Delicious, McIntosh, and Spartan. Plots were not replicated within each variety and the plot size was 2x3 trees in the Red Delicious and Spartan varieties and 4x4 trees in the McIntosh variety.

The sprays were applied with a one-sided air-blast sprayer set to deliver 60 gallons of spray mixture per

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TABLE 1—Control of the fruit-tree leaf roller and eye-spotted bud moth with pre-bloom treatments.

Material and amount per acre	Time of application	Apple Variety	Post-bloom Counts		Harvest Counts	
			Larvae per 300 clusters		% fruit injured by	
			Leaf roller	Bud moth	Leaf roller	Bud moth
Dormant oil—6 gal. (200-220 vis)	$\frac{1}{2}$ inch green	McIntosh	13	82	4.5	15.0
		Spartan	17	66	9.8	15.1
		Delicious	15	76	5.6	13.2
Dormant oil—6 gal. (200-220 vis) Azinphos-methyl—2½ lb. 25% W.P.	$\frac{1}{2}$ inch green early pink	McIntosh	0	0	0.5	1.1
		Spartan	0	3	0.5	0.9
		Delicious	0	2	0.8	1.1
Azinphos-methyl—2½ lb. 25% W.P.	early pink	McIntosh	0	2	0.7	1.3
		Spartan	0	1	0.8	0.7
		Delicious	1	0	0.6	0.6
Azinphos-methyl—5 lb. 25% W.P.	early pink	McIntosh	0	0	0.5	0.9
		Spartan	0	0	0.4	0.7
		Delicious	0	0	0.5	0.8
Check	—	McIntosh	17	107	7.4	17.6
		Spartan	17	79	9.6	18.1
		Delicious	16	61	8.1	12.2

acre at 100 psi. Some treatments were applied on 10 April, when the McIntosh buds were in the $\frac{1}{2}$ inch green stage, and the remainder were applied on 27 April, when the McIntosh buds were in the pre-pink stage. The early sprays were dormant oils directed against the over-wintering eggs of the fruit-tree leaf roller and overwintered larvae of the eye-spotted bud moth. The later applications of azinphos-methyl at 5 and $2\frac{1}{2}$ lb. were designed to control the newly emerged larvae of the two insects.

The treatments were evaluated by post-bloom counts of larvae, and by harvest counts of injured fruit. The post-bloom counts were made by examining a total of 300 fruit clusters per treatment and recording the number of fruit-tree leaf roller and eye-spotted bud moth larvae. At harvest, all of the fruit on the two centre trees in each treatment was examined and the fruit-tree leaf roller and eye-spotted bud moth damaged apples were recorded.

The effect of the various treatments on predacious mites was determined by leaf counts taken at intervals throughout the season. Samples consisted of 100 leaves picked at random from each treatment. The leaves were run through a mite brushing machine (Henderson and McBurnie, 1943), and the mites counted with the aid of a stereoscopic microscope.

Results

The data from the plots are summarized in Table 1. Dormant oil at the dosage used, was ineffective against the fruit-tree leaf roller and the eye-spotted bud moth. Azinphos-methyl at either $2\frac{1}{2}$ lb. or 5 lb. gave excellent control of the two insects.

There was no difference in the control obtained within the three apple varieties, and the check counts showed the infestation to be fairly uniform.

Mite counts showed no difference in the number of phytoseiid mites on the check trees and those treated with dormant oil or azinphos-methyl at $2\frac{1}{2}$ lb. No phytoseiids were found on trees treated with azinphos-methyl at 5 lb.

The white apple leafhopper, *Typhlocyba pomaria* (McAtee), was present in high numbers on all three apple varieties in the orchard. There was no indication that any of the pre-bloom treatments controlled the leafhoppers and their feeding caused severe leaf damage in all plots.

Discussion

These data indicate that a pre-bloom application of azinphos-methyl will adequately control the fruit-tree leaf roller and eye-spotted bud moth should these insects become a problem in orchards under a program of autocidal control of the codling moth. Azinphos-methyl at a dosage of $2\frac{1}{2}$ lb. 25% W.P. per acre gives adequate control, and does not adversely affect predatory phytoseiid mites. The pre-pink timing of the application would not interfere with a sterile codling moth release program, since in most seasons it is not necessary to release moths until after the trees have blossomed. One danger in an application of azinphos-methyl close to the bloom period is toxicity to bees and other pollinating insects. This danger will be minimized if the sprays are applied as early as possible during the pink stage of tree development.

Acknowledgments

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THE FIRST DISCOVERY OF FREE-LIVING LARVAE OF THE EAR TICK, *OTOBIOUS MEGNINI* (DUGES), IN BRITISH COLUMBIA

G. B. RICH¹ and J. D. GREGSON¹

ABSTRACT

In the south Okanagan Valley a cave in a rock face was investigated after a visiting dog became infested with the ear tick, *Otobius megnini* (Duges). Larvae of the ear tick were found in abundance, on the floor and dropping from the ceiling. The cave is a shelter and resting place for a protected band of bighorn sheep which is known to be heavily infested. Near the opening of the cave were larvae of the winter tick, *Dermacentor albipictus* Packard, and a nymph and an adult female of the wood tick, *D. andersoni* Stiles.

The ear tick, *Otobius megnini* (Duges), 1884, was described from specimens collected in Mexico. Subsequent records show it to be parasitic on larger wild mammals and domestic animals in most of the United States, southeastern British Columbia, Mexico, Peru, Chile, Bolivia, and northern Argentina (Rich, 1957). In addition to this natural distribution, it has been introduced into, and has become established in Hawaii, India, and South Africa. This tick infests only the ear canals of its host, entering as a larva and emerging as a fed nymph. The minute, white, six-legged larvae are extremely active, and are readily mistaken for mites by casual observers. The final moult occurs off the host, and the adult is free-living and non-feeding.

A nymph removed from the ear of a house cat at Ewing's Landing on Okanagan Lake in 1941, was the first ear tick recorded in British Columbia (Gregson, 1956). Subsequently nymphs were collected rather generally from the ears of mountain goats, mountain sheep, elk, mule and white-tailed deer, domestic cattle and dogs in that portion of the province south of the 52nd parallel and east of the 121st meridian (Rich, 1957, and subsequent records). Since 1955 at least 16 cattle are known to have died as a direct result of ear tick infestations

(Rich, 1957, and subsequent records). Despite diligent searching, free-living adults, and until March 29, 1968, free-living larvae had not been found.

The life history in British Columbia is not completely known. Despite extensive searching only a single autumn record of engorged larvae has been made from a mule deer shot at Blackpines, October 24, 1951. From much less extensive spring sampling, numerous records of engorged larvae have been made from mule deer shot during February to early May, inclusive, in the Adams Lake, Ewing's Landing, Lumby and Short's Creek areas. These records may be variously interpreted as indicating either that (a) some overlapping of generations occurs, (b) hatching occurs in the fall with some infestations occurring, but the majority of larvae overwintering for host infestation in the spring, or (c) overwintering occurs largely as eggs with hatching in very early spring. Laboratory studies have shown that the larvae are attracted to warm-blooded animals.

Free-living larvae were discovered in the South Okanagan Valley as follows: Dr. Hauston, of Penticton, informed S. Cannings² that in early 1968 he had found a cave in the Vaseux Lake area to be "alive" with fleas, and a Corgi dog that had been in the vicinity of the cave had been subsequently infested with ear ticks. Cannings, with J. D. Gregson, explored the cave on March 29, 1968, but could not find fleas. Upon leaving the

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cave, Gregson was annoyed by many "biting" sensations in his hair. As he had been bareheaded, but had been careful not to touch his head against the cave roof, he suspected that the cause of the bites had dropped from the roof on to his head. However, nothing could be found in his hair. Later, in early evening, he felt "biting" sensations on his forehead, and a minute, white "mite" was found. Examination under magnification proved the "mite" to be a larval ear tick. As it appeared probable that this larva, and the ear tick infestation of the Corgi, may have originated at the cave, the cave was re-examined on April 4, 1968.

The cave is in a vertical rock-face with a southwesterly exposure, about one mile south of Gallagher Lake and directly east of Inkaneep Provincial Park. The cave is approached up a talus slope of the type usual to interior British Columbia, with an almost vertical lip of rock between the talus and cave. This feature makes the cave almost inaccessible to large mammals other than mountain sheep and goats, and agile humans. The cave is known locally as a shelter and resting place for mountain sheep of the Vaseux Lake band, which is known to be heavily infested with ear ticks (Gregson, 1956, and other records). The cave is approximately 40 feet wide at the opening and about 20 feet deep, with the roof sloping almost to the floor at the rear.

Larval winter ticks, *Dermacentor*

albipictus Packard, and a nymphal and a female wood tick, *D. andersoni* Stiles, were collected at the top of the talus. The approach talus and the cave provided ample evidence of mountain sheep. Larval ear ticks were abundant on the floor and roof of the cave. A small cotton sheet spread on the floor yielded numerous larvae each time it was turned over. The party knotted white handkerchiefs on their heads before entering, and were careful not to touch the roof. Numerous larvae appeared on the handkerchiefs within a few minutes after entering. To confirm that these dropped from the roof, a rubber water bottle filled with warm water and covered with black silk cloth was held about 4 to 6 inches from the roof for one minute intervals, and up to 10 larvae per interval were recovered from the cloth. A piece of white nylon voile was spread on the floor with small pieces of dry ice beneath it, but this did not yield any greater number of larvae than an equal area of the white cotton sheet. No adult ear ticks or shed nymphal skins were found.

This sequence of events indicates that the ear tick larvae had been active in this cave for several months prior to the April 4 visit. A warm-blooded animal resting in the cave during this period would have become heavily infested. It is of interest that three of British Columbia's most important tick species were collected in one place, which is also a favoured locale for mountain sheep.

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ANNOTATED LIST OF FOREST INSECTS OF BRITISH COLUMBIA PART XIV, ENNOMINAE (GEOMETRIDAE)

B. A. SUGDEN¹

ABSTRACT

The mature larvae of 57 species of forest geometrids are described briefly and their distribution and hosts, as determined from samples collected by personnel of the Forest Insect and Disease Survey, are given.

The larvae of Ennominae are often tuberculate, with colors and patterns resembling the leaf-stems and twigs of the host trees. Pupation may occur in foliage or bark crevices of trees and shrubs or in the litter on the forest floor. Ennominae overwinter as eggs or pupae and occasionally as partly grown larvae.

Frequent outbreaks of several species of Ennominae have caused damage of economic importance to mature, polesized and reproduction forest trees.

Brief larval descriptions of *Semiothisa* and *Caripeta* spp. with notes on their hosts and distributions were published earlier in the Proceedings of the Entomological Society of British Columbia (Ross and Evans 1958 and 1959).

ENNOMINAE

Bapta semiclarata Wlk.—*Prunus* spp., *Amelanchier* spp., *Crataegus* sp. (2 records), *Alnus* sp. (1), *Pseudotsuga menziesii* (Mirb.) Franco (2). Southern to central British Columbia and Vancouver Island, common. LARVA: 1 inch; head small, pale green, reddish-brown markings on sides extending to vertex; body robust, smooth; two color phases: (a) immaculate pale green, anal shield marked with reddish-brown; (b) pale green with broken, reddish-brown ad-dorsal lines extending from TII to A8; anal shield and anal prolegs marked with reddish-brown; venter immaculate.

Deilinia variolaria Gn.—*Salix* spp. Central and southern interior British

Columbia, rare.² LARVA: 1½ inches; head horizontal, pale green marked with pinkish-violet; body slim, pinkish-orange with medium brown mid-dorsal spots flanked by pale mauve patches on A1-8; subspiracular area of TI-III suffused with violet extending into upper part of legs; anterior of abdominal prolegs violet, anterior of anal prolegs marked with a violet line; venter pinkish-orange A1-6, remainder yellowish-green, pale yellowish-green midventral line bordered by deep pink adventral lines A1-6.

Deilinia erythemia Gn.—*Salix* spp. Throughout British Columbia, common. LARVA: 1 inch; head horizontal, pale green, lower sides with reddish-brown line; body slim, pale green, diffused white subdorsal stripes, dark reddish-brown middorsal spots flanked by paler reddish-brown patches on posterior of TIII and A1-4, less distinct on A5-7; subspiracular stripe formed by a powdering of reddish-brown spots extending onto upper legs of TI-III, becoming gradually fainter posteriorly; sides of ventral and anal prolegs marked with purplish-brown; venter pale green with yellowish-white midventral line.

Deilinia exanthemata bryantaria Tayl.—*Salix* spp. Throughout interior British Columbia, extending to the Coast in the Prince Rupert District, apparently more numerous in central and west central portions, uncommon. LARVA: 1½ inches; head pale green, thin reddish line on lower sides; body slim, pale green, A1-6 with reddish middorsal spots, faint on A1 and 6; sides of abdominal prolegs marked with pale reddish-brown; venter immaculate.

Itame anataria Swett—*Alnus* spp.,

¹ Forest Entomology Laboratory, Department of Forestry and Rural Development, Vernon, B.C.

² i.e. rare in Forest Insect and Disease Survey random beating collections which are taken only from trees and a few species of the larger shrubs.

Betula spp., *Salix* spp. Central to southern interior and southern coastal regions of British Columbia. LARVA: 1 inch; two color phases with intermediates (a) head buff, profusely marked with dark brown; body, dark mauve with small dark brown mid-dorsal patches, bordered laterally with pale buff on A1-4; indistinct pale purple addorsal lines; irregular brown subdorsal lines, outer line darkest; narrow pale buff supraspiracular line bordered by dark brown; broad pale cream subspiracular stripe; dark brown spots caudad of spiracles on A2-5; dark brown subventral patches on A1-5; venter similar to dorsum but paler; (b) head pale cream profusely marked with dull orange; body pale yellowish-buff, irregular middorsal, addorsal and subdorsal lines pale reddish-brown; narrow pale yellowish supraspiracular stripe bordered above by dark brown and below by light brown lines; broad pale yellow subspiracular strip; prominent dark brown subventral patches on A1-5; thoracic legs marked with dark brown and prolegs with pale reddish-brown; venter similar to dorsum, A1-4 with small oval, pale brown midventral spots.

***Itame exauspicata* Wlk.**—*Betula* spp., *Alnus* spp., *Salix* spp. (2 records), *Prunus pensylvanica* L. f. (1), *Corylus cornuta* Marsh. var. *californica* (A.DC) Sharp (1), interior British Columbia north to 56° latitude; common. LARVA: 1 inch; head tan profusely marked with dark brown; dorsum of TI-III medium brown with indistinct bands of dark brown flecked with pale reddish-brown; abdomen medium brown, irregular pale reddish-brown dorsal stripe bordered by dark brown, anal shield pale buff with dark brown setal bases; lateral area reddish-brown banded with dark brown extending to venter, spiracles pale yellow; venter pale reddish-brown marked with dark brown, A2-5 with large pale reddish-brown midventral spots bordered by dark brown.

***Itame plumosata* B. & McD.**—*Acer glabrum* Torr. var. *douglasii* (Hook.)

Dipp. Southern central British Columbia, rare. LARVA: 1½ inches; head green; body pale yellowish-green, spiracles pale yellow.

***Itame bitactata* Wlk.**—*Alnus* spp. Southern interior British Columbia, uncommon. LARVA: 1 inch; three color phases: (a) head dull orange with pale tan markings, front marked with pale yellow inverted V; body smooth, pale orange with prominent dark brown setal bases, irregular pale yellow addorsal lines bisecting indistinct pale yellow diamond-shaped pattern on A1-5, pale yellow subdorsal lines; broad yellow subspiracular stripe banded anteriorly with dark brown on T1 and A1-8; venter with midventral spots on A1-4, T1 and A1-5 banded with pale brown; (b) dark phase similar; head blackish with pale inverted V, greenish-grey body and dull black markings; (c) head green with pale yellow inverted V on front; body green with pale yellow dorsal lines; pale yellow subspiracular stripe; pale greyish-green oval midventral spots on A1-4, greyish-green crochets on prolegs.

***Protitame matilda* Dyar**—*Populus tremuloides* Michx., *P. trichocarpa* Torr. & Gray, *Salix* spp., *Alnus sinuata* (Regel) Rydb. (1 record). Throughout interior British Columbia north to 54° latitude and on Vancouver Island, common. LARVA: ⅞ inch; head medium green marked with pale reddish-brown; body smooth, robust, pale green; dorsum with a reddish tinge extending to lateral, pale reddish-brown addorsal and pale greenish-yellow subdorsal lines; indistinct pale yellowish-green supraspiracular stripe; venter pale green with a yellowish tinge, immaculate.

***Protitame hultsaria* Tayl.**—*Populus tremuloides*, *Salix* spp. Interior British Columbia north to 56° latitude, uncommon. LARVA: ⅞ inch; head reddish-brown sides extending to vertex, front green; body smooth, robust, apple-green, broad reddish-brown dorsal stripe extending to A8; sides and venter immaculate.

***Itame loricaria julia* Hlst.**—*Popu-*

lus tremuloides, *P. trichocarpa* (2 records), *Salix* spp. (2). Throughout British Columbia and on Vancouver Island, but most common in the central and northern Interior. LARVA: $1\frac{1}{8}$ inches; two color phases with intermediates: (a) head purplish-brown with tan markings; body smooth, purplish-brown, pale tan addorsal lines, banded with dull black except on TI and III and A1, 8 and 9; dull black lateral bands on TII, III and A2-6; spiracles pale yellow encompassed by irregular dull black patches; irregular subspiracular stripe on A1-5; venter pale purplish-brown banded with dull black A2-5; (b) head green; body green, pale yellowish-white middorsal and addorsal lines; spiracles pale yellowish-green, pale yellow subdorsal line; small, midventral spots on A1-4, reddish-brown crochets.

Elpiste lorquinaria Gn.—*Alnus* spp., *Salix* spp., *Betula* spp. (2 records). Southern British Columbia and Vancouver Island, uncommon. LARVA: $1\frac{1}{8}$ inches; similar to *I. l. julia*.

Stenoporpia excelsaria Stkr.—*Pseudotsuga menziesii*, *Pinus contorta* Dougl., *P. ponderosa* Laws. Southern interior and coastal regions of British Columbia, uncommon. LARVA: $1\frac{3}{8}$ inches; head slightly bilobed, golden buff marked with dark grey herringbone pattern on vertex; body robust, medium grey shading to golden buff on lighter areas, indistinct pale dorsal line bordered by thin dark grey addorsal lines, irregular diamond pattern bordered by dark grey on A1-7, dark grey bands extending to venter on A1-8, darkest on A2 and narrowed on TI-III, prominent subspiracular fringe of white, palmate setae, 2 to 5, on A1 and 3; venter pale yellowish-buff, indistinct pink ventral line, setal bases outlined with pink.

Stenoporpia albescens Hlst.—*Pseudotsuga menziesii*, *Abies amabilis* (Dougl.) Forbes, *A. grandis* (Dougl.) Lindl., *Picea sitchensis* (Bong.) Carr., *Tsuga heterophylla* (Raf.) Sarg., *T. mertensiana* (Bong.) Carr., *Pinus*

contorta, *P. monticola* Dougl., *Thuja plicata* Donn. Western British Columbia, Vancouver and Queen Charlotte Islands, common on Vancouver Island, uncommon elsewhere. LARVA: $1\frac{1}{2}$ inches; head slightly bilobed, tan marked with grey; body smooth, greyish shading to brown in lighter areas, pale broken addorsal line bordered by blackish addorsal lines, indistinct diamond pattern irregularly outlined in black on TII-III and A1-8, on A2 black markings coalesced to create a band; lateral with diagonal line posterior of spiracles on TI and A1-8, prominent subspiracular fringe of white, palmate setae, 3 to 5 on A1-3; venter pale yellowish-buff.

Stenoporpia separataria Grt.—*Pseudotsuga menziesii*. Southern and central interior British Columbia, rare. LARVA: $1\frac{3}{8}$ inches; similar to *S. excelsaria*. Larval period for *S. satisfacta* May-June; larvae of *S. excelsaria* occur August-September.

Stenoporpia satisfacta B. & McD.—*Pseudotsuga menziesii*, *Tsuga heterophylla*, *Pinus ponderosa*, *P. monticola*, *Abies lasiocarpa*. Southern and central interior British Columbia, uncommon. LARVA: $1\frac{3}{8}$ inches; similar to *S. excelsaria*. Larval period for *S. satisfacta* May-June; larvae of *S. excelsaria* occur August-September.

Coniodes plumogeraria Hlst.—*Quercus garryana* Dougl., *Salix* sp. (1 record), *Acer glabrum* var. *douglasii* (1). Southern British Columbia and Vancouver Island; Victoria, Goldbridge, Summit Lake and an adult caught in flight at Vernon, rare. LARVA: $1\frac{1}{2}$ inches; head moderately bilobed, pale grey heavily patterned with black; body slim, sparsely pilose, pale greyish-buff, pale dorsal line bordered with black on TI-II and A7-8, black tuberculate setal bases, addorsal tubercles on A1-3 and 8, most prominent on A2 and 3; brownish-orange patch around spiracle and tubercle on A1, prominent spiracular tubercle on A1, prominent spiracular tubercles on A2-3 and less prominent on A7-8; venter pale buff, TI-III and A1 suffused with pink, A2-5 broadly

banded with black, tubercular black setal bases.

Eranniss vancouverensis Hlst.—*Betula* spp., *Salix* spp., *Alnus* spp., *Acer* spp. Central and southern British Columbia, common; occasionally localized infestations of short duration. LARVA: 1½ inches; head granulose, pale tan to dull orange; body minutely spiniferous, pale greenish-yellow to pale yellowish-orange with narrow blackish lines extending to anal plate and coalesced on supraspiracular of A1-8, spicules more pronounced on A8 and anal plate; spiracles yellow with black margins; venter immaculate, paler than dorsum.

Lycia ursaria Wlk.—*Betula* spp., *Alnus* spp., *Salix* spp., *Populus tremuloides*. Interior British Columbia south of 55° latitude, rare. LARVA: 2¾ inches; head rounded, pale mauve spotted with black; body robust, dull purple with small flattened tubercles on A1-5, reddish-purple addorsal, subdorsal, suprespiracular, spiracular, subventral and adventral stripes finely edged with black; venter of TI-III and A7-9 pale yellow, TI-III marked with large midventral spots.

Lycia rachelae Hlst.—*Alnus* spp. (3 records), *Salix* spp. (2), *Amelanchier alnifolia* Nutt. (1). Interior British Columbia, rare. LARVA: 1½ inches, head whitish mottled with dark brown; mauve to pinkish-mauve with fine brown maculation, dorsal lines obscure; irregular pinkish-mauve spiracular stripe flecked with yellowish-white, prominent black spiracles; venter like dorsum but paler.

Biston cognataria (Gn.) — *Salix* spp., *Betula* spp., *Populus tremuloides*, *Alnus* spp., *Prunus* spp., *Larix occidentalis*, Nutt. (1 record). Throughout British Columbia and Vancouver Island, common. LARVA: 3 inches; head granulose, deeply bilobed, buff or grey marked with darker shades of grey, brown or orange; body sparsely granulate, variable grey, brown, orange or green, prominent tubercles on addorsal TI and supraspiracular A5 less prominent on addorsal A8; in-

distinct pattern on TI-III and A6-8; midventral tubercles on A2-4, largest on A3; subventral fringe of short pale setae between prolegs extending onto posterior of ventral prolegs.

Phaeoura mexicanaria Grt.—*Pinus ponderosa*. Southern interior British Columbia, rare. LARVA: 2¾ inches; head granulose, deeply bilobed, brownish with black and buff markings; body robust, with minute spines, pale grey marked with black, medium brown and buff, dorsum of A1-4 with pale V markings outlined with black, darker on A5-7, setal bases pale, tuberculate, subdorsal tubercles on A1-3, largest on A2, small addorsal tubercles on A8; lateral flecked with minute whitish tubercles; venter paler than dorsum marked with black, TII-III broadly banded with black.

Gabriola dyari Tayl.—*Tsuga heterophylla*, *Pseudotsuga menziesii*, *Abies amabilis*, *A. grandis*, *A. lasiocarpa*, *Thuja plicata*, *Picea sitchensis*, *P. engelmanni*, *P. glauca*, *Pinus monticola*, *P. contorta*, *P. ponderosa*, *Larix occidentalis*. South of 56° latitude in British Columbia and on Vancouver and Queen Charlotte Islands, common. LARVA: 1¼ inches; two color phases: (a) head medium brown, slightly bilobed, vertex sparsely granulose; body stout, rugose, creamy-buff marked with brown and black, TI-III with indistinct pale middorsal line, A1, 2, 4, 8 and 9 pale flecked with brown, A3, 5-7 darker with + shaped pale middorsal marks and black diagonal subdorsal flecks; small tuberculate setal bases, partly fused middorsal tubercles on TII and A8, small subdorsal tubercles A1-8, prominent bilobed spiracular tubercles TII and A2-8; broad, irregular creamy-buff spiracular stripe on TI, A1-5, 7-9 and onto anal plate; venter pale brown with indistinct midventral lines; (b) similar to (a) but lacking black markings and will dull orange replacing brown

Euchlaena johnsonaria Fitch—*Alnus sinuata*. Interior British Columbia south of 54° latitude, rare. LARVA: 1⅞ inches; head somewhat

quadrate, horizontal, dull bluish-grey sparsely marked with creamy-buff; body twig-like, pale buff marked with grey, purplish-grey, medium-brown and black; dark dorsal lines TI-III and A1 indistinct on remainder of dorsum, A1-3 with pale diamond pattern, pale chevrons on A6-8, flattened transverse ridge on A1 bordered with black lines, small tubercles on A5, 6 and 8; lateral with pale grey or pale buff blotches, paler than dorsum; venter pale with pale grey ventral lines outlined by fine irregular black lines; A1 with large pale spot, small tubercles on A1-5.

Euchlaena marginata albertanensis Swett—*Salix* sp. Southern interior British Columbia, rare. LARVA: $1\frac{1}{4}$ inches; head somewhat quadrate, horizontal, pale grey with herring-bone pattern on sides and vertex composed of tiny purplish dots; body slim twig-like, pale grey marked with medium brown, pink, yellow, white and black; indistinct black dorsal lines; small prominent addorsal tubercles on A2-8; black except on A2, yellow bordered with black; setal bases tuberculate; indistinct black and dull white lateral lines; venter with irregular black lines, posterior of thoracic legs heavily marked with black.

Euchlaena tigrinaria sirenaria Stkr.—*Betula* spp. Interior British Columbia south of 54° latitude, rare. LARVA: $1\frac{1}{4}$ inches; head pale grey with pale pinkish-buff markings and whitish transverse band on lower front bordered above with black; body slim, twig-like, wider anteriorly, pale whitish-buff mottled with grey, pinkish-brown and black, middorsal and addorsal lines on TI-III and A3-5, indistinct on A1 and 2, pale chevrons on A6 and 7, pale anal plate, pale transverse ridge bordered with black on A1, prominent addorsal tubercles on A5 and 8; broad but indistinct brownish supraspiracular band on TI-III and A1-5, A6-8 mottled with dark brown and pinkish-brown, short black spiracular tubercles on A7-8; small ventral tubercles on A1-5; tho-

racic legs marked with black.

Epirrhanthis substriataria danbyi Hlst.—*Salix* spp., *Pseudotsuga menziesii* (1 record), *Larix occidentalis* (1), *Populus tremuloides* (1). Southern British Columbia and Vancouver Island, uncommon. LARVA: $1\frac{1}{2}$ inches; head whitish to pale buff marked with brown, herring-bone pattern on sides; body pale buff, maculation medium brown, TI-III with dark brown middorsal line, paler and indistinct on remainder of dorsum, TII, III and A1-7 with indistinct chevrons, transverse ridge, with small tubercles, bordered posteriorly with a narrow dark brown line on A8; lateral paler than dorsum; venter pale, marked with irregular, pale pinkish lines.

Campaea perlata Gn.—*Salix* spp., *Betula* spp., *Populus tremuloides*, *Alnus* spp., *Pseudotsuga menziesii*, *Tsuga heterophylla*, *Thuja plicata*, *Pinus contorta*, *Picea* spp., common. Throughout British Columbia and Vancouver Island. LARVA: $1\frac{3}{4}$ inches; head pale mauve with black spots; body twig-like pale yellow, occasionally greenish, with medium grey, brownish-orange and black markings, indistinct pale subdorsal lines, black dorsal band on A2, brown cervical shield, pale areas around spiracles on A1-3; venter pale, subventral fringe of hair-like tubercles, abdominal prolegs on A5 and 6, posterior pair larger.

Anthelia taylorata Hlst.—*Tsuga heterophylla*. Southwestern British Columbia and Vancouver Island, rare. LARVA: $1\frac{3}{8}$ inches; similar to the following species: *A. hyperborea* Hlst. (Personal communication, D. Evans, Department of Forestry and Rural Development, Victoria, B.C.)

Anthelia hyperborea Hlst.—*Tsuga heterophylla*, *T. mertensiana*, *Pseudotsuga menziesii*, *Thuja plicata*, *Abies amabilis*, *A. lasiocarpa*, *A. grandis*, *Picea engelmanni*, *P. glauca*, *P. sitchensis*, *Pinus monticola*, *Salix* spp., *Alnus* spp. South of 56° latitude in British Columbia, on Vancouver and Queen Charlotte Islands, com-

mon. LARVA: $1\frac{3}{8}$ inches; head yellowish-buff marked with medium brown, yellowish-buff stripes from vertex to labrum; body smooth tapering anteriorly, yellowish-buff marked with medium and light brown, mid-dorsal, addorsal and subdorsal lines pale yellowish, irregular subdorsal stripes extending onto head and anal shield; narrow pale yellow supra-spiracular line bordered with medium brown, setal bases black, spiracles outlined with black; venter paler than dorsum, marked with alternate lines of pale yellow and pale pinkish-brown, midventral spots of pale brown.

Plagodis phlogosaria Gn.—*Betula* spp., *Alnus* spp., *Salix* spp. Throughout British Columbia and Vancouver Island, uncommon. LARVA: $1\frac{1}{4}$ inches; head retractile, pale grey liberally marked with black; body pale grey heavily suffused with purplish and reddish-brown, transverse blackish bands on TI-II, TII with lateral swellings, prominent blackish transverse ridge on A5 extending to lateral; prominent tubercles on posterior of anal prolegs just below anal shield, venter paler than dorsum, adventral spots, dark grey on A3-5, fused and velvety black on A1-2; TI-II and A7-9 pale buff.

Anagoga occiduaria Wlk.—*Alnus* spp., *Betula* spp., *Salix* spp. South of 55° latitude in British Columbia and on Vancouver Island, uncommon. LARVA: $1\frac{1}{8}$ inches; two color phases: (a) head small, bilobed, pale grey heavily suffused with purple, indistinct blackish markings; body pale grey suffused with purple, pale subdorsal stripe on TI-III and A1, one pair of small subdorsal spots A2-9, blackish transverse ridge extending to lateral on A5; small tubercles on lateral, TI-III pale flecked with pinkish mauve; venter with small tubercles, black V markings on A1-2; (b) similar but with brown, dull orange and yellow replacing purple, mauve and pale grey.

Hyperetis amicaria H.-S.—*Alnus* spp., *Betula* spp., *Salix* spp. (2 rec-

ords), *Populus tremuloides* (1). South 56° latitude in British Columbia, on Vancouver and Queen Charlotte Islands, uncommon. LARVA: $1\frac{1}{4}$ inches; two color phases: (a) head small, pale yellow, sides marked with minute brown spots; body smooth, pale yellow, A1-9 suffused with dull orange, TII-III wider than other body segments, TI with medium brown subdorsal spots, TII with medium brown transverse band from addorsal extending to subspiracular, transverse band on TII from subdorsal to subspiracular, transverse ridge on A5 medium brown marked anteriorly with yellow; lateral paler than dorsum, spiracular spots on A2-5; venter paler than dorsum, wide irregular midventral line on A1-6; (b) head green, sparse pale pink maculation; body green, dorsum faintly suffused with pale pink, medium brown transverse ridge on A5, brown extending onto lateral, spiracles outlined with black, setal bases brown; ventral setal bases brown.

Nematocampa filamentaria Gn.—*Pseudotsuga menziesii*, *Tsuga heterophylla*, *Picea engelmanni*, *P. glauca*, *Thuja plicata*, *Abies lasiocarpa*, *A. grandis*, *Larix occidentalis*, *Pinus monticola*, *P. contorta*, *Salix* spp., *Alnus* spp., *Betula* spp. Throughout British Columbia and on Vancouver Island, most common in Columbia Forest Region, rare on coast. LARVA: $1\frac{1}{4}$ inches; tone of markings variable; head small pale yellow, dark brown maculation on sides and front; body slim, dull white to pale yellow, middorsal line TI to A1, indistinct on TI, pale addorsal and subdorsal lines TI-III extending onto apex, two prominent, cone-like addorsal tubercles on A1, four long filaments on A2 and 3, two small tubercles fused to form a transverse ridge on A8, A1 marked with dull orange, A2-3 suffused with pink; pale subspiracular line TI-III extending onto head TI-II and A1-5 indistinctly banded, A5 with oblique marking, A6-9 pale; venter banded, dark irregular midventral line with pale margins A1-8.

Metarranthis duaria septentrion-aria B. & McD.—*Betula* sp. (1 record), *Populus tremuloides* (1), *Salix* sp. (1). Southern interior British Columbia and Vancouver Island, rare. LARVA: $1\frac{3}{8}$ inches; head slightly bilobed, pale yellow sparsely flecked with pink, front narrowly outlined with dark brown; body robust, pale yellow, medium brown markings with bluish overtone, indistinct, irregular dorsal lines, pale inverted U-shaped marking on A2, one pair of small whitish addorsal spots outlined with black A1-8, black addorsal tubercles on A8, black line extending from tubercles to spiracles on A8; irregular yellow lateral lines; pale yellow ventral lines, setal bases velvety black forming band on A1-3.

Metanema inatomaria Gn.—*Populus tremuloides*, *P. trichorcarpa*. South of 57° latitude, interior British Columbia, rare. LARVA: $1\frac{1}{4}$ inches; head small, pale buff marked with dark brown, herring-bone pattern on sides; body pale buff marked with shades of brown and black, pale inverted V pattern on A1-3 and 5, pattern coalesced on A3-4 extending obliquely on A4 to subspiracular line, pale middorsal line bordered irregularly with black TI-III, pale indistinct subdorsal lines extending onto vertex; lateral with narrow black line obliquely through spiracles A1-6, dark brown subspiracular stripe bordered irregularly above with a yellow line extending onto head; venter pale yellow flecked with pink.

Metanema determinata Wlk.—*Salix* spp. Interior British Columbia: Summit Lake, Mile 53 Alaska Highway and also recorded from Creston (J. R. J. Llewellyn-Jones), rare. LARVA: $1\frac{1}{8}$ inches; head small, flattened, pale buff profusely marked with brown; body, twig-like, pale buff mottled with brown, pale diamond markings on A1, 2, 4 and 5 on A3 extending obliquely to lateral, one pair of small, flattened dark brown addorsal tubercles on A1 to 5; dark brown subspiracular line extending on underside of head, darkest on TI-

III and A5-9; venter pale, fine, pinkish maculation.

Selenia alciphearia Wlk.—*Populus tremuloides*, *Alnus* spp., *Salix* sp. (1 record). Throughout British Columbia, including Vancouver Island, rare. LARVA: $1\frac{1}{2}$ inches; head horizontal and flattened, pale yellow, lower front and sides marked with dark brown; body slender to A3 remainder thicker, pale brown, A6-9 greyish, all marked with darker shades of brown, pale addorsal lines extending onto head on TI-III and A6-9; dark brown transverse ridges with one pair of small addorsal tubercles on A4 and 5, ridges with fine white markings; lateral of TI-III suffused with reddish-brown, wide dark brown oblique bands on A4 and 5 extending to, and bisecting venter, venter of A2 and 3 with narrower brown bands, pale yellow midventral stripe A1-3 broadly bordered with pale brown.

Selenia kentaria G. & R.—*Alnus* sp. Interior British Columbia at Annis and Mile 53 Alaska Highway, rare. LARVA: $1\frac{1}{2}$ inches; similar to *S. alciphearia* but with one pair of addorsal tubercles on A1-3, smallest on A3, dark brown frosted with grey, transverse ridges rusty dark grey marked with white, venter dark grey with small tubercles on A1-2.

Pero behrensarius Pack.—*Pseudotsuga menziesii*, *Tsuga heterophylla*, *Thuja plicata*, *Abies grandis*, *A. lasiocarpa*, *A. amabilis*, *Picea engelmanni*, *P. glauca*, *P. sitchensis*, *Pinus contorta*, *P. ponderosa*, *P. monticola*, *Larix occidentalis*. South of 55° latitude in British Columbia and on Vancouver Island, common. LARVA: 2 inches; head moderately bilobed, yellowish-buff marked with brown on sides and front; body smooth, slender, tapering anteriorly, pale grey; dorsum greyish-brown V markings darkest on TI-III and extending obliquely to venter on A1-7; venter with pale irregular midventral stripe.

Pero morrisonarius Hy. Edw.—*Tsuga heterophylla*, *Pseudotsuga menziesii*, *Thuja plicata*, *Picea sitchensis*, *P. glauca*, *Abies grandis*, *A.*

lasiocarpa, *Salix* spp., *Alnus* spp. South of 56° latitude in British Columbia and on Vancouver Island, uncommon. LARVA: 2 inches; similar to *P. behrensarius* but head more strongly bilobed, pale fawn marked with medium brown, lower half of front pale; body slim with transverse ridge on A8, one pair of prominent subventral tubercles on A2; body brownish with paler longitudinal shades, rarely with broad alternating bands of pale grey and rich brown.

Pero mizon Rindge—*Pseudotsuga menziesii*, *Thuja plicata*, *Tsuga heterophylla*. South of 56° latitude in British Columbia and on Vancouver Island, rare. LARVA: 2 inches; similar to *P. morrisonarius* but lacks prominent subventral tubercles on A2; dorsum of A1 and 4 marked with black.

Phengommataea edwardsata Hlst. —*Pseudotsuga menziesii*, *Pinus contorta*, *P. ponderosa*, *P. monticola*, *Picea sitchensis*, *Tsuga heterophylla*. Central to southern British Columbia, including Vancouver Island, uncommon. LARVA: 1¾ inches; head pale green marked on the sides and front with reddish-brown; body smooth, robust, medium green, prominent yellowish-white subdorsal lines extending onto head; yellowish-white spiracular lines wider posteriorly, spiracles pale yellowish outlined with reddish-brown; venter paler than dorsum with yellowish-white subventral lines.

Enypia venata Grt.—*Tsuga heterophylla*, *T. mertensiana*, *Pseudotsuga menziesii*, *Abies amabilis*, *A. grandis*, *A. lasiocarpa*, *Thuja plicata*, *Picea sitchensis*, *P. engelmanni*, *P. glauca*, *Pinus monticola*, *P. contorta*. Central to southern British Columbia, Vancouver and Queen Charlotte Islands, more common in western portions of the province. LARVA: 1¼ inches; head small, pale, marked with dark brown lines, herringbone pattern on sides; body smooth, robust, pale yellowish-buff with longitudinal pattern of medium buff, discontinuous blackish middorsal,

addorsal and subdorsal lines; broken, irregular, blackish lateral and ventral lines.

Enypia griseata Grossb.—*Pseudotsuga menziesii*, *Abies lasiocarpa* (2 records), *Picea engelmanni* (1), *P. glauca* (1). Central to southern interior British Columbia, uncommon. LARVA: 1¼ inches; head small, pale green, dark brown markings on upper front bordering cleavage line, sides of head suffused with pale reddish-brown; body smooth, pale green, dark green middorsal line, white addorsal lines extending onto head; white spiracular line marked with reddish-brown on TI-III; venter with white midventral and subventral lines.

Enypia packardata Tayl.—*Tsuga heterophylla*, *T. mertensiana*, *Pseudotsuga menziesii*, *Abies amabilis*, *A. grandis*, *A. lasiocarpa*, *Thuja plicata*, *Pinus monticola*, *P. contorta*. South of 56° latitude in western British Columbia, Vancouver and Queen Charlotte Islands, common. LARVA: 7⁄8 inch; head reddish-brown with pale vertices; body smooth, light green with dark dorsal, subdorsal and supraspiracular lines, yellowish spiracular line. (Personal communication, D. Evans, Dept. of Forestry and Rural Development, Victoria, B.C.)

Nepytia umbrosaria nigrovenaria Pack.—*Pseudotsuga menziesii*, *Tsuga heterophylla*, *Abies grandis*, *Pinus contorta*, *P. monticola*, *Thuja plicata*, *Picea sitchensis*. Southern British Columbia including Vancouver Island, uncommon in coastal regions and rare in the Interior. LARVA: 1¾ inches; head pale brown; body distinctively striped; dorsum cream-colored with broken orange dorsal and subdorsal lines; dark brown-red laterally, indistinctly light-lined and edged black; ventral surface pale brown-green. (Personal communication, D. Evans, Dept. of Forestry and Rural Development, Victoria, B.C.)

Nepytia freemani Munro — *Pseudotsuga menziesii*, *Tsuga heterophylla*, *Picea engelmanni*. Interior British Columbia south of 54° latitude, common. Localized outbreaks, of short

duration, have occurred in reproduction and pole-sized stands of *P. menziesii*. LARVA: 1¼ inches; head square, vertex and sides tan, front pale yellow, immaculate except for dark setal bases and ocelli; body slim, broad rich tan dorsal stripe with black margins bordered by narrower yellow subdorsal stripes; rich tan supraspiracular stripe marked irregularly with black and finely outlined with black; broad yellow spiracular stripe, narrower than subspiracular stripe, finely outlined in black extending onto thoracic legs; broad yellow ventral stripe, pale tan adventral stripe finely bordered with black, pale pinkish subventral stripe.

Nepytia phantasmaria Stkr.—*Tsuga heterophylla*, *Pseudotsuga menziesii*, *Thuja plicata*, *Picea sitchensis*, *Abies amabilis*, *A. lasiocarpa*, *A. grandis*, *Pinus monticola*, *P. contorta*. South of 54° latitude in western British Columbia and Vancouver Island, common. Localized but severe outbreaks have occurred resulting in mortality of mature *T. heterophylla* and *P. menziesii* located in municipal and city parks. LARVA: 1½ inches; head green with black dots; body smooth, lime green with dark edged, yellowish subdorsal and spiracular lines. (Personal communication, D. Evans, Dept. of Forestry and Rural Development, Victoria, B.C.)

Lambdina fiscellaria lugubrosa Hlst.—*Tsuga heterophylla*, *Pseudotsuga menziesii*, *Thuja plicata*, *Abies lasiocarpa*, *A. amabilis*, *A. grandis*, *Picea engelmanni*, *P. sitchensis*, *P. glauca*, *Larix occidentalis*, *Pinus contorta*, *P. monticola*, *Alnus* spp., *Salix* spp., *Betula* spp., *Acer* spp. South of 57° latitude in British Columbia, Vancouver and Queen Charlotte Islands, common; frequent outbreaks have occurred causing damage of economic importance to mature western hemlock forests. LARVA: 1½ inches; head pale yellowish-buff minutely spotted with brown and black, sparsely marked with larger black spots; body smooth, transverse ridge on A8, pale yellowish-buff marked longitu-

dinally with fine, irregular, pale greyish and brownish lines; irregular black addorsal lines, TI-III with addorsal spots, A1-7 each with four addorsal spots, A8 with six addorsal spots; pale yellow addorsal stripe marked intermittently with pale brownish-orange; lateral suffused with pale grey, darker than dorsum, marked with fine longitudinal grey lines; dark grey, broken supraspiracular stripe; spiracular stripe brownish grey; venter pale marked longitudinally with fine irregular pale grey lines.

Lambdina somniaria Hlst.—*Quercus garryana*, *Salix* spp., *Acer circinnatum*, *Alnus rubra*. Southern Vancouver Island where localized outbreaks occur, common. LARVA: 1½ inches; similar to *L. f. lugubrosa* but generally paler.

Besma quercivoraria Gn.—*Betula* spp., *Salix* spp., *Alnus rubra*. South of 56° latitude in British Columbia and on Vancouver Island, uncommon. LARVA: 1½ inches; slim and twig-like, lateral swelling on T2, transverse ridge, with addorsal tubercles, extending to lateral on A3, addorsal tubercles on A6, two color phases with intermediates: (a) head pale yellowish-green occasionally with reddish markings on sides; body immaculate pale green; (b) head reddish-brown with fine white irregular lines on vertex; body reddish-purple, prominent parts marked with black, small white markings around or near setal bases; lateral with blackish patches around spiracles; (c) head yellowish-green with reddish markings darkest on sides; body green suffused with pale red darkest on A6-9, prominent parts dark reddish-brown.

Sicya macularia agyllaria Wlk.—*Salix* spp., *Populus tremuloides*, *Alnus* spp., *Betula* spp. South of 55° latitude in British Columbia including Vancouver Island, rare. LARVA: 1¾ inches; head pale yellow, lower vertex and posterior portion of sides marked with reddish-brown; body slim, twig-like, lateral swelling on TII, one prominent horn-like mid-

dorsal tubercle on A3 and 5, transverse ridge and small addorsal tubercles on A8, A3 with lateral swelling and small spiracular tubercles; dorsum reddish-purple; lateral reddish-purple, paler around spiracles; occasional specimens with broad whitish spiracular stripe continuing onto anal shield; venter reddish-purple with whitish midventral stripe.

Deuteronomus magnarius Gn. —

Betula spp., *Populus tremuloides*, *Salix* spp., *Alnus* spp. South of 55° latitude in British Columbia, including Vancouver Island, uncommon. LARVA: 1½ inches; head rounded, horizontal, pale greyish-white marked with brown; body slim, twig-like, brownish, slightly raised ridges on A2 and 5, two tubercles on A8, venter paler than dorsum.

Synaxis jubararia Hlst. —

Tsuga heterophylla, *Pseudotsuga menziesii*, *Abies amabilis*, *A. lasiocarpa*, *A. grandis*, *Thuja plicata*, *Picea engelmanni*, *P. sitchensis*, *P. glauca*, *Larix occidentalis*, *Pinus contorta*, *Salix* spp., *Alnus* spp., *Populus* spp., *Betula* spp. South of 56° latitude in British Columbia, including Vancouver Island, common. LARVA: 1½ inches; head small, buff patterned with minute dark brown spots coalesced to form lines; body slim and twig-like, wider from A6-9, TII with lateral swelling; pale buff marked with shades of grey and brown; pale indistinct middorsal line margined with black TII and III, diamond markings on A1-2, chevrons on A3-8, smallest on A6-9, TI and II of lateral pale, TIII and A1-9 greyish brown, darker posteriorly, lateral of abdominal prolegs with white vertical stripe; venter paler than dorsum.

Tetracis cachexiata Gn. —

Acer glabrum, *Salix* spp., *Betula* spp. Cen-

tral to southern interior British Columbia, uncommon. LARVA: 1⅞ inches; head small, horizontal, dull yellowish-white marked with medium brown on vertex, two short black lines extending from vertex to mid-front; body slim wider from A6-9, TII with lateral swelling and small addorsal tubercles, subspiracular tubercles on A1 and 2; subdorsal tubercles on A4 and 5, brown transverse ridge extending to venter on A8; prominent parts blackish, black middorsal line on A5-8; pale lateral patches on TI and II extending onto head, subspiracular tubercles on A1-2 dark brown surrounded by brown outlined with black creating short oblique markings; venter paler posteriorly, setal bases dark.

Prochoerodes forficaria combinata

McD.—*Acer glabrum*. Southern interior of British Columbia, rare. LARVA: 1⅞ inches; head rounded, small, pale grey or buff marked with dark brown, narrow brown band below vertex extending onto and partly bisecting front, two prominent whitish spots on front; body slim, pale grey, marked medium brown densely spotted with black, indistinct mid and subdorsal lines, indistinct diamond pattern A1-7, setal bases whitish and slightly tuberculate, prominent addorsal tubercles inclined anteriorly on A8, broken pale spiracular line, setal bases pale and slightly tuberculate, venter pale whitish-grey with pale medium brown longitudinal lines, dark grey middorsal spots and setal bases.

Acknowledgment

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**APHIDIUS RUBIFOLII N. SP. (HYMENOPTERA:
APHIDIIDAE), A PARASITOID OF MASONAPHIS
MAXIMA FROM BRITISH COLUMBIA**

MANFRED MACKAUER¹

ABSTRACT

Aphidius rubifolii n. sp. is described from coastal British Columbia. The parasitoid appears to be specific to *Masonaphis* species that feed on thimbleberry, *Rubus parviflorus* Nutt.

A large material of aphid parasitoids collected in British Columbia in recent years contained representatives of an undescribed species of genus *Aphidius* Nees. In Smith's (1944) key to the Nearctic *Aphidius* the new species runs to *rosae* Haliday. It differs from that species, in the female, mainly by its more slender petiole and the lighter colour which, in fact, is more similar to that of the European *lonicerae* Marshall. Small specimens of *rubifolii* resemble *polygonaphis* (Fitch) in some respects, but may be distinguished by the shape of the valvula 3 which in *polygonaphis* is almost three times as long as the maximum width as compared to less than twice as long as wide in *rubifolii*.

Descriptions

Female—Length, 1.8 - 2.7 mm; length of antenna, 1.3-2.1 mm; length of forewing, 1.7-2.6 mm.

Head: smooth, highly polished, sparsely hairy, contracted towards occiput; temples approximately twice as wide as transverse eye diameter. Eyes ovate, shortly pubescent. Face as wide as high (index 0.93-0.96). Malar space about twice as wide as length of second antennal segment. Antennae: with 18 or, rarely, with 17 or 19 segments (sgts. 3/17, 25/18, 2/19), distinctly shorter than body. Segment 3 slender, three times to three and one-half times as long as wide, one-sixth shorter than segment 4. All flagellar segments uniformly hairy; the last segment up to two times longer than preceding,

tapering distally. Thorax: smooth, shiny, very sparsely hairy. Notauli indicated at cephalic end only. Prescutellar groove sharply impressed, smooth. Scutellum more or less flat, broadly triangular. Propodeum with distinct longitudinal and transverse carinae; area centralis narrowly pentagonal, almost closed; areae posteroexternae concave, smooth. Wings: hyaline. Pterostigma of forewing narrow, elongate, approximately four times as long as broad, one and one-half times as long as metacarp (index 1 : 0.26 : 0.60); first abscissa of radius one-sixth longer than second; discocubital vein completely pigmented. Hind wings moderately broad, bluntly rounded apically. Abdomen: smooth, shiny, terminal segments sparsely hairy. Petiole slender, about four times as long as wide across spiracles; spiracular tubercles small but distinct; anterior third of tergite finely sculptured, more or less smooth apically; central carina distinct separating the two well-defined lateral depressions. Genitalia of typical form; valvula 3 stout, with a distinct basal hook. Legs: slender, moderately hairy. Colour: yellowish-testaceous. Head above antennae, second and following antennal segments (except anellus and base of third), mesoscutum, scutellum, postnotum, ovipositor sheaths, and last tarsal segments fuscous to black; abdominal segments 3 and following yellowish-beige, banded, the darker bands separated by more or less wide yellowish rings.

Male—Length, 2.0-2.8 mm; length of antenna, 2.0-3.0 mm; length of forewing, 2.1-2.6 mm.

Morphologically similar to female, except for sexual differences. Anten-

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nae with 19-21 segments, rarely with one or two segments more or less (sgts. 2/18, 4/19, 7/20, 4/21, 1/23), approximately as long as body. Petiole slender, more parallel-sided than in female, three to three and one-half times as long as wide across spiracles; tergite weakly sculptured, central carina more or less distinct. Colour: fuscous. Malar region, cheeks, first antennal segment and anellus, prothorax, parts of meso- and metasterna, lower half of propodeum, petiole, a variable-sized central area of the third abdominal tergite, and legs (except upper side of hind femora and tarsi which are obfuscated), testaceous to fusco-testaceous.

Cocoon—Inside the indurated skin of the dead host aphid. Colour of mummy beige to yellowish-brown; emergence hole generally between cornicles, roundish to ovate, with smooth edges.

Types—Holotype: ♀, Vancouver, B.C., 29.vii.1965, B. D. Frazer (C.N.C., No. 10,005). Allotype: ♂ (same locality and date), (C.N.C. No. 10,005). Paratypes: ♀ ♂ (see material examined). Type locality: Vancouver, U.B.C. Campus, British Columbia, Canada. Type host: *Masonaphis (Oestlundia) maxima* (Mason, 1925); (Homoptera:

Aphididae, Aphidinae) on *Rubus parviflorus* Nutt. (Rosaceae).

Material examined — Described from a large series of material which was reared from *Masonaphis maxima* on *Rubus parviflorus* in coastal British Columbia: Vancouver, U.B.C. Campus, 3.-29.vi.1965, B. D. Frazer; Vancouver, Point Grey district, 25.v.1965, M. Mackauer.

COMMENTS

The host range of *Aphidius rubifolii* appears to be restricted to species of *Masonaphis* Hille Ris Lambers that feed on thimbleberry, *Rubus parviflorus* Nutt. It is relatively common as a parasitoid of *M. (Oestlundia) maxima* (Mason) which evidently is the main host. In addition to *maxima* the parasitoid possibly may also attack *M. (O.) davidsoni* (Mason), since it was collected on occasion from mixed colonies containing both species of aphids on thimbleberry.

The only other record of a parasitoid that attacks genus *Masonaphis* is that of *Aphidius rosae* which was reared from *M. (O.) rubicola* (Oestlund) on *Rubus* by MacGillivray and Spicer (1953) in New Brunswick. This record may or may not pertain to the new species, *A. rubifolii*.

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MASONAPHIS MAXIMA (MASON) (HOMOPTERA: APHIDIDAE), AN APHID ON THIMBLEBERRY WITH AN UNUSUAL LIFE HISTORY¹

B. D. FRAZER AND A. R. FORBES

ABSTRACT

A two-year study of *Masonaphis maxima* (Mason) on thimbleberry, *Rubus parviflorus* Nutt., revealed an unusual life history. The eggs hatched in late March or early April, and the fundatrices matured and reproduced a month later. Males and females were produced in late May or in June and egg-laying had started by July. This early egg-laying coincided with the cessation of production of new growth by the host plant. Additional description of the fundatrix is included.

Introduction

Three species of aphids occur commonly on thimbleberry, *Rubus parviflorus* Nutt., around Vancouver, B.C. These are *Amphorophora parviflori* Hill, *Masonaphis (Oestlundia) maxima* (Mason), and *Masonaphis (Oestlundia) davidsoni* (Mason). They are easily separable by the following key:

1. Clavate cornicles with a few slight striations just below the flange but not reticulated.....*A. parviflori* Hill
Clavate cornicles distinctly reticulated 2
2. Apterous viviparous female..... 3
Alate viviparous female..... 4
3. 6-14 sensoria on third antennal segment.....*M. maxima* (Mason)
20-23 sensoria on third antennal segment..... *M. davidsoni* (Mason)
4. Fore wings each with conspicuous dark spot at the tip.....*M. maxima* (Mason)
Fore wings without dark spot.....*M. davidsoni* (Mason)
M. maxima is by far the common-

est and most numerous of the three. All are vectors of thimbleberry ring spot virus (Stace-Smith, 1958). MacGillivray (1958) has added to the published descriptions of *M. maxima* and *M. davidsoni*. Hill (1958) described *A. parviflori*. The present paper presents additional description of the fundatrix of *M. maxima* and biological data on this species.

Description of the Fundatrix

Since MacGillivray's (1958) description is based on a single specimen, we add the following description:

Similar to apterous viviparous female but with shorter antennae. Body 2.69-4.70 mm long. Antennae 0.6-0.8 of the length of body; third segment with 1-4 secondary sensoria; unguis considerably shorter than third segment and 2.7-3.3 times as long as the base of sixth segment. Cornicles only slightly swollen, maximum diameter 1.1-1.2 times the smallest, and reticulated on distal 0.06-0.11 of their length.

¹ Contribution No. 135, Research Station, Research Branch, Canada Department of Agriculture, Vancouver, B.C.

Lengths in mm and number of secondary sensoria:

No.	Body	Ant.	Corn.	Cauda	Antennal segments				Sensoria on III
					III	IV	V	VI	
1	4.33	2.88	0.99	.20	.61	.43	.46	.18+.52	2, 1
2	4.67	3.11	1.07	?	.69	.46	.49	.20+.59	3, 4
3	4.70	2.94	1.00	.29	.65	.43	.47	.20+.54	2, 1
4	4.70	3.13	1.14	.35	.76	.48	.50	.19+.53	3, 3
5	2.69	2.36	1.05	.34	.63	.48	.42	.14+.46	3, 4
6	3.88	2.49	0.98	.35	.65	.49	.46	.18+.50	3, 4

(1-6, from *Rubus parviflorus*, Vancouver, B.C.; 1-2, April 12, 1966; 3-6, April 26, 1967.)

Biology

M. maxima is a large non-economic aphid living on the undersides of young leaves and growing terminal shoots of thimbleberry, *Rubus parviflorus* Nutt. Thimbleberry is a native shrub of the forest understory, particularly common along partially shaded edges of clearings.

The following life history data were gathered from extensive, naturally occurring plots of thimbleberry on the campus of the University of British Columbia. Frequent observations were made until first instar fundatrices were found on the plants. Plots were sampled at least weekly thereafter. A number of colonies were reared on thimbleberry in pots in a screenhouse and greenhouse.

The entire life cycle occurs on thimbleberry. The eggs hatched during the period March 22-31 in 1966 and April 1-10 in 1967 and fundatrices were mature and reproducing a month later. Progeny of the fundatrices were mostly apterous; only 10-15 per cent were alate. Some male nymphs were produced in the third generation starting as early as May 17. Male nymphs were easily distinguished by their bright red color. The first mature males were noted on May 31 in 1966 and on June 13 in 1967. Mature oviparae were found at about the same time. Egg laying had commenced by early July. The last aphids were found on August 9 in 1966 and on July 18 in 1967. Thus there are only 3 or 4 parthenogenetic generations each year. Maximum density of 525 aphids per cane was reached by July 12 in 1966 and the numbers decreased very rapidly thereafter. Maximum density of 252 aphids per cane was reached by June 20 in 1967.

Eggs were found on buds, leaves, and stipules of stems 2-3 inches long arising from the crown. These parts remain green throughout the winter. Few eggs were found on stems and leaves well above the ground. Some eggs were found on dead leaf litter close to thimbleberry crowns. In the screenhouse, large numbers of eggs

were laid on the clay pots containing the thimbleberry plants; very few were laid on the plants themselves. The eggs are dark green when laid and turn black and shiny in 3-7 days depending on the temperature. They are ellipsoid, 1.55-1.69 mm in length and 0.78-0.85 mm in width.

The aphids were heavily preyed upon by syrphid larvae, primarily *Metasyrphus fumipennis* Thomson, *Scaeva pyrastris* (L.), *Syrphus ribesii* (L.), *S. opinator* O.S., and *S. torvus* O.S. (det. J. R. Vockeroth), starting with the fundatrices. During April and early May each year, adult cantharids (*Podabrus* sp.), preyed upon the aphids. At least two species of predacious cecidomyiids were prominent in the colonies from late June onwards. No coccinellid eggs, larvae, or adults were found in the two years of sampling. Parasitism reached 15 per cent. The primary parasites were: *Aphidius rubifolii* Mackauer and a *Praon* sp. (det. M. J. P. Mackauer).

In the greenhouse or screenhouse where predators and parasites were excluded and where the more catastrophic meteorological agents were eliminated, *M. maxima* attained densities sufficient to defoliate and kill thimbleberry plants. In the field, on the other hand, no infestation observed in three seasons of observations was severe enough to cause visible damage to the host.

Dispersal of alates was mainly to new growth on plants within the immediate area. Yellow pan water traps and yellow sticky boards near the observation plots caught only two alate *M. maxima*. Isolated plots of thimbleberry which did not have fundatrices in the spring received few immigrant alates from other plots and populations on them remained low. Apterous dispersed themselves by falling to new growth of new plants arising from the stolons beneath the old plants and from the crown.

Body size of both apterous and alate viviparae varied with the time of collection. Measurement of the lengths of the body, antennal seg-

ments, cornicles, and cauda generally showed the shortest lengths in aphids collected during April, the greatest in those collected during May, and intermediate values in those collected during June.

Field, greenhouse, and screenhouse observations showed that the aphids would not settle or feed on fully mature leaves or stems; they fell from the plants and died whenever there was no succulent growing tissue available.

Discussion

The reduction in the number of parthenogenetic summer generations with very early production of sexuales and eggs on the primary overwintering host is unusual in aphids. In a temperate climate such as at Vancouver, aphids typically migrate in the spring from primary woody overwintering hosts to secondary herbaceous summer hosts (heteroecy), or sometimes spend their entire life cycle on a single host. In either case 10 or more parthenogenetic generations may be produced between April and November, and sexuales, if present, occur in September, October, and November.

Abbreviated life cycles such as that of *M. maxima* have been reported for only a few other aphids. For *Dysaphis devecta* (Walker), on apple, Hille Ris Lambers (1945) and Stroyan (1963) report a short life cycle of three parthenogenetic generations with production of sexuales in June or July. For *Brachycaudus rociadae* (Cockerell), on larkspur, Hottes and Frison (1931), report oviparae in Illinois on May 13 and state that as a result, this aphid passes the larger part of the year in the egg stage. Other authors, however, report sexuales of this species on the same host in Colorado on October 3 (Gillette and Palmer, 1932). For *Kakimia essigi* (Gillette and Palmer), on columbine, Hottes and Frison (1931) mention early production of sexuales and eggs (p. 133), but also describe sexual forms collected at Urbana on October 15 (p. 337). Similarly Palmer (1952) reports sexu-

ales of this species from October 3 to November 29. For *Aphis farinosa* Gmelin, Hille Ris Lambers (1945) reports overwintering eggs in June and July. Robinson (1968) has just reported the presence of oviparae of *Kakimia canadensis* Robinson in early summer in British Columbia and Idaho.

Hottes and Frison (1931) suggest that early production of sexuales and early oviposition is a response to progressive unsuitability of the host and is a substitute for heteroecy and that in the case of *B. rociadae* it is an adaptation to the short period of growth of the host. In a recent review Kennedy and Stroyan (1959) point out that the period of maximum favourability of the sap of any plant is short and that the production of both alate viviparae and sexuales in aphids is a result of this. Alates are able to exploit a fresh host and sexuales produce resistant overwintering eggs. In the case of *M. maxima*, the production of sexuales and eggs certainly coincides with the cessation of production of new growth by the host plant and there is ample evidence that the aphid cannot live on fully mature leaves. Other aphids react to unfavourable host plant condition in other ways. The sycamore aphid, *Drepanosiphum platanoides* (Schr.), shows a density dependent reduction in its reproductive rate (Dixon, 1963 and 1966), and several *Periphyllus* spp. on maple aestivate as peculiar first instar sexuparae called dimorphs (Essig and Abernathy, 1952).

The habit noted with this aphid of laying appreciable numbers of eggs on debris on the ground near its host plant would also seem to be unusual. Aphid eggs are usually laid on or near dormant buds, or on the bark on limbs or canes.

Other instances have been documented of seasonal variation in the body size of aphids. In Israel, Bodenheimer and Swirski (1957), report three species of aphids as being at their largest about March and smallest between August and October.

Bodenheimer and Swirski regard body size as an expression of growth conditions for the aphids and tend to attribute the variation they noted to the nutritive status or physiological condition of the host plant. Other evidence would support this view (Kennedy and Stroyan, 1959; Dixon, 1963 and 1966). For *M. maxima* a combined effect of host plant condition and temperature is indicated. In April the thimbleberry is succulent and favourable for maximum growth, but the temperature is less than op-

timum; in May both the host plant condition and temperature are favourable; in June the host plant is less succulent and higher temperatures are somewhat less favourable.

Because of its short life-cycle, its complement of predators and parasites, its relationships with the host plant, and its relatively easily determined age-distribution, *M. maxima* has been chosen for further studies of the biotic and abiotic factors influencing aphid population dynamics.

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A RECORD OF *RHAGOLETIS INDIFFERENS* CURRAN FROM CRESTON, BRITISH COLUMBIA

J. C. ARRAND AND W. S. PETERS

In 1962 *Rhagoletis indifferens* Curran was identified from collections in cherry orchards at Creston. Identification was confirmed by J. F. McAlpine, Canada Department of Agriculture, Research Branch, Ottawa. Previously only *Rhagoletis fausta* (Osten Sacken), had been recorded from the Kootenay area of British Columbia. The presence of *R. indifferens* has greatly increased the problem of fruit fly control in that area.

Although this is the first record of *R. indifferens* in Canada, the *R. cingulata* that have been reported from

the Fraser Valley and Vancouver Island were undoubtedly *R. indifferens*. Specimens from both locations which have been examined fit the description of *R. indifferens*.

According to G. L. Bush (1966), *R. cingulata* is not found west of Iowa in North America. Although the range of *R. indifferens* is largely within the range of the main wild host, bitter cherry, *Prunus emarginata*, it is present in the commercial cherry area of Western Montana beyond the range of bitter cherry.

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THE WORLD OF AN INSECT

By REMY CHAUVIN

World University Library, McGraw-Hill Book Co. New York and Toronto. 1967. Pp. 254. \$2.45.

But \$2.75 at the UBC Bookstore, a high price for a paperback that is not really a teaching or reference text. Without question Prof. Chauvin is a first rate entomologist and certainly a great teacher. The flyleaf says the book was written for university students, the title suggests for laymen. But numerous unexplained scientific names and jargon terms would discourage laymen. The book needs a glossary and list of insects and plants mentioned. The lack of a proper bibliography is a very serious omission. True, there are 122 references chosen for their general application and for further reading, but these may or may not be referred to. For most of the citations in the text, often without dates, the reader is invited to go to the Zoological Record, Review of Applied Entomol-

ogy, Biological Abstracts, etc. In a book of this size it seems shortsighted to begrudge four or five pages for references. In the first that interested me which I tried to trace, the senior author's name turned out to be not just misspelled but wrong, and it took a professional librarian some time to verify this. Perhaps the intention is to give students practice in searching literature. In general, the book is not explicit enough for an undergraduate text and contains simply too many errors. Thus on p.203: Sheals (1955) used DDT "at 75-80% of the gamma isomer . . . the only active part in the commercial product." The date was 1956 and the isomer was *p,p'*. In a short reference to Balachowsky (p.241) on biological control, six misstatements or outright errors occur within nine lines. In quotation from Balachowsky (p.226) we read of the fruit-growing valley of Yatima, Washington. There are others.

The author has been ill-served by

his translator and proof readers. Harold Oldroyd is a competent translator but a neglectful rewriter subject to unforgivable lapses into literal translation such as: "... for the beetles the most abundant and most frequent ..." (p. 138); or "... have been equally detected by ..." (p. 108); alfalfa is nearly always referred to as the field of alfalfa, e.g. "... the field of alfalfa is a perennial crop." The proofreading is inexact, leaving too many misspellings even of names, and a pair of transposed captions for full-page pictures.

Physically the book is attractive despite an infuriating tendency to close itself. The paper and type are good, the numerous photographs are well chosen and the line drawings are simple, very clear, and improved by judicious use of green ink. The same applies to the graphs, which are mostly re-drawn and re-lettered, simplified, and occasionally over-simplified. The 15 tables are well worked-over, but at least one is reduced beyond the point of clarity, by the omission of units (p. 147).

Canadian entomologists come off well. The work of Morris, Wellington, Watt, Turnbull, and Stanley is discussed at some length and with approval amounting to enthusiasm.

Wellington, Watt, and Beirne appear in the bibliography. French entomologists fare even better, almost to the point of chauvinism (no pun intended). They are said to be distinct from Americans, who are preoccupied with overpopulation, tending to rear large populations of grain insects then applying statistics without asking whether the biology of two *Tribolium* differs from that of a singleton (p. 85). French workers reject "... the soft pillow of simple, mechanical factors upon which certain research workers take it easy." (p. 86). In the bibliography only 14 of 122 titles are in French, 16 are in German, and 40 appeared in U.S. publications. Chapter 4, Populations in Nature, is largely based on German studies in cultivated field crops.

Chauvin is loquacious but not unduly so and the book moves, albeit slowly. It adds up to a usable and, in spite of my complaints, a curiously enjoyable book. For all its shortcomings I should recommend it strongly for graduate students, who could not help but be stimulated. But as a teaching and reference text it cannot compete with Southwood's *Ecological Methods*.

—H. R. MacCarthy

METRIC CONVERSION

Contributors of papers on laboratory studies should use the metric system exclusively. Use of the metric system in reporting the results of field studies is a desirable ultimate objective. Since it is difficult to replace immediately such standard concepts as lb/acre by the unit kg/hectare, yards by meters, or miles by kilometers, the following table of conversion factors is presented.

1 in.=2.54 cm	1 ft ³ =28.3 dm ³	1 cm=0.394 in
1 yard=0.914 m	1 acre=0.405 hectares	1 m=3.28 ft=1.094 yards
1 mile=1.61 km	1 lb/acre=1.12 kg/hectare	1 km=0.621 mile
1 lb.=453.6 g	1 lb/in ² (psi)=70.3 g/cm ²	1 kg=2.2 lb
1 gal (U.S.)=3.785 liters	1 lb/gal (U.S.)=120 g/liter	1 liter=0.264 gal (U.S.)
1 gal (Imp)=4.546 liters	1 lb/gal (Imp)=100 g/liter	1 liter=0.220 (Imp)
	1 dm ³ =0.0353 ft ³	
	1 hectare=2.47 acres	
	1 kg/hectare=0.89 lb/acre	
	1 g/m ² =0.0142 psi	
	1 g/liter=0.83 lb/100 gal (U.S.)	
	=1000 ppm	
	1 g/liter=1 lb/100 gal (Imp)	

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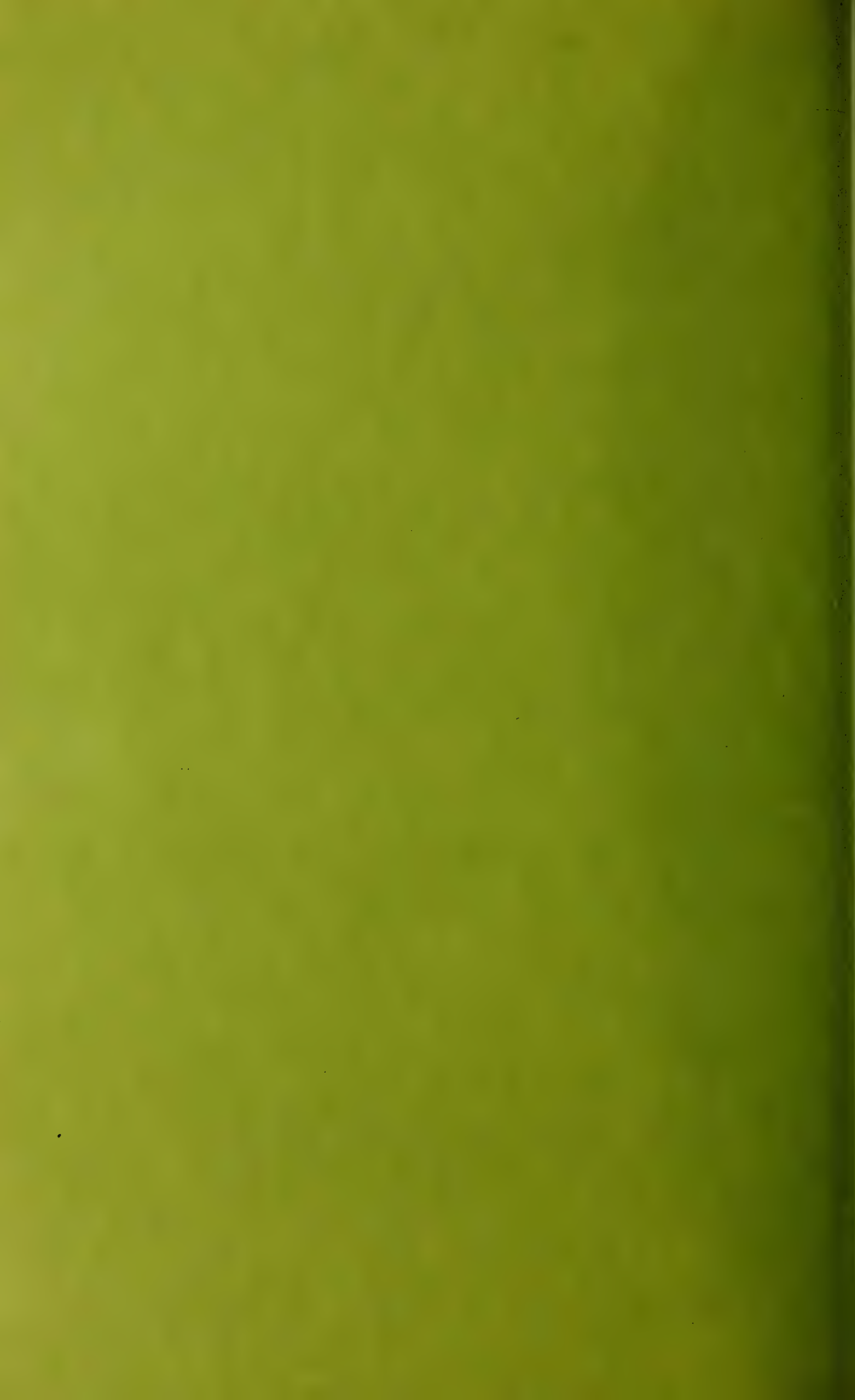
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The style, abbreviations and citations should conform to the *Style Manual for Biological Journals* published by the American Institute of Biological Sciences.

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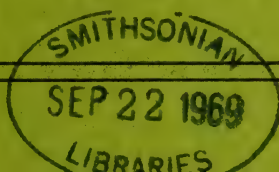
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A METHOD FOR DETERMINING THE DOSAGE-MORTALITY CURVE OF MALATHION AGAINST THE PEA APHID, *ACYRTHOSIPHON PISUM* (HARRIS) (HOMOPTERA:APHIDIDAE)¹

W. D. PEARSON²

ABSTRACT

The procedures of a reliable method for establishing the dosage-mortality curve for malathion and the pea aphid, *Acyrtosiphon pisum* (Harris), are described and evaluated. They include the choice of insecticide formulation, the conditions for rearing and collecting, the holding of treated aphids, and the analysis of mortality data. The LD₅₀ of actual malathion in acetone solution to the pea aphid is 23.5 nanograms per aphid. The 95% fiducial limits about this estimate are 22.9 and 24.1 nanograms per aphid. The slope, \pm S.E. ($n=7$), of the log-dosage: probit-mortality line is 5.5 ± 0.4 .

Introduction

The success of the Aphididae as a group is partly due to the evolution of a specialized cycle which is closely adapted to the annual cycle of the host plant. The main features of the aphid cycle are: a thelytokous, or female-producing, spring and summer phase during which one or many generations occur, living usually on herbaceous plants; and a sexual fall generation, usually on a woody plant, which permits gene segregation and recombination, and retains evolutionary potentiality. The viviparous phase allows rapid increase of numbers and ensures that the population at the end of the phase will consist almost entirely of individuals which were adapted to conditions during the summer phase. These characteristics are advantageous in exploiting new ecological niches.

Some species living in mild climates have secondarily lost the sexual fall generation and reproduce entirely by thelytoky. In these species the genetic constitution is presumed to

be extremely stable (Suomalainen, 1962; White, 1945). Nevertheless, instances of resistance to insecticides in the Aphididae during the past decade have given reason to doubt this stability. Stern (1962) reported an organophosphate-resistant population of *Therioaphis maculata* (Buckton) in California, an area where the few oviparae present produce only non-viable eggs (Dickson, Laird and Johnson, 1958). Two populations of organophosphate-resistant *Myzus persicae* (Sulzer) have been found in greenhouses, where sexual reproduction is unlikely to have occurred (Dunn and Kempton, 1966; Baerecke, 1962). The mechanisms whereby resistance evolved are unknown, and there is thus interest in them from the academic and applied points of view.

Methods used in the past for toxicological studies on aphids have not been adequate. Dunn and Kempton (1966), in their attempt to trace the decline of organophosphate resistance in a clone of *M. persicae*, were not able to make valid comparisons between generations since different concentrations were used to determine median lethal times. When the same concentrations were used the

¹ Taken from a thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in the Division of Plant Science, University of British Columbia.

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susceptible clone appeared to develop four- and five-fold resistance. The only conclusion they could draw was that resistance declined when selection pressure was removed. The present study was prompted by the increasingly clear need for a precise method for establishing dosage-mortality curves for aphids.

A log-dosage: probit-mortality line (ld-p line), the transformed equivalent of a dosage-mortality curve, provides estimates of the toxicity of the insecticides to individual aphids and by extension to the population. Since these estimates are reference points they must be repeatable, for repeatability is the best indication of reliability. Only with repeatable estimates can investigation begin on the mechanisms whereby resistance evolves.

Procedures of the Method

Rearing Aphids

Colonies of the pea aphid, *Acyrtosiphon pisum* (Harris), used throughout this investigation, were reared on broad bean, *Vicia faba* L., variety Exhibition Long Pod. These were grown in a potting mixture of equal parts of sphagnum moss and fine sand. No additional nutrients were added.

Aphids were reared in insect-proof cages 30.5 cm wide, 45.7 cm high, and 44.5 cm deep. Ventilation was provided by a forced air system delivering filtered air at the rate of 0.17 cu m per minute. The temperature inside the cages was maintained at 21.7 ± 2 C, and the vapor pressure deficit at 12.5 ± 3.5 millibars. Sixteen hours illumination per day was provided by six 2.4 m cool white fluorescent tubes placed 35 cm above the soil surface in the pots. The light intensity ranged

from 2100 to 5000 lux, from the soil surface to the ceiling of the cage. Aphids were reared under these conditions for three generations before being treated.

A simple method was used to provide uniformly large, healthy, apterous aphids by hundreds, which had not been subjected to any adverse condition. Colonies were started by placing 20 nine-day-old aphids in each of two pots containing 12 plants, 2 to 8 cm high. These aphids produced about 440 nymphs during 24 hours, after which the adults were removed.

Collecting Aphids

Aphids were collected when they were 9 ± 0.5 days old. Those not on the plants in the cage were removed and destroyed. Single plants were cut off at the soil line and held over a large glass dish, the inner sides of which were coated with Fluon³. Apterous adults were gently brushed from the plant into the dish with a squirrel hair brush. Casts and nymphs were removed from the dish and from the adults. The aphids collected from one or two plants were evenly distributed among the eight petri dishes used to hold them prior to treatment. Sub-samples were taken until 50 aphids for each of seven treatments and a control had been collected. Aphids used in control treatments were weighed before being treated as a check on uniformity and to gauge the effects of handling.

The aphids were then transferred singly from the holding dish with a vacuum pencil to 10-cm arenas, the floors of which were of 12-strand per cm saran screen. Each arena was subdivided into three compartments by Fluon-coated Kodapak⁴ cylinders, 4 cm diameter by 1.3 cm high. Fifteen aphids were placed in each arena, 4 in one compartment, 5 in the second and 6 in the third.

³ A polyterafluoroethylene dispersion manufactured by Imperial Chemical Industries Ltd.

⁴ A transparent plastic sheeting obtained from Burnaby Orchids, Burnaby, B.C.

Choice of Insecticide Formulation

Secondary standard malathion⁵ of 96% purity was chosen as the test insecticide because it is an organophosphate, the class of insecticide involved in most cases of aphid resistance to insecticides, and because it has low mammalian toxicity. Test solutions were made by diluting a 1% (w/v) solution of the malathion in acetone. Acetone was found by trial to be best for topical application because it spread quickly and evenly, evaporated rapidly, and was non-toxic in the quantity used.

Application of Insecticide

To apply the insecticide to individual aphids, a Yale B-D Luer 0.25 ml glass hypodermic syringe, fitted with a No. 26 square-end, right-angled needle was clamped into the holder of a modified Micro-Metric SB-2⁶ syringe micro-buret. The drive spindle of this applicator was fitted with a plywood disc in which 20 equally spaced cogs had been cut. A pawl mounted on the base of the applicator permitted the operator to devote his entire attention to the tip of the needle and the aphids during operation. Turning the disc from one cog to the next advanced the plunger 0.051 mm and delivered a 0.514 μ l droplet of insecticide solution. This droplet was transferred by touching the tip of the needle to the dorsum of an aphids abdomen. The insecticide spread at once to cover the entire abdomen. A different random sequence of treatments was used for each replicate.

⁵ 0, 0 - dimethyl S-(1, 2 - dicarbethoxyethyl) phosphoro dithioate, obtained from Cyanamid of Canada Limited, 1 City View Drive, Rexdale, Ontario.

⁶ Manufactured by Micro-Metric Instrument Co., Cleveland, Ohio.

⁷ Adapted by P. M. Morse and E. A. Reimer, Statistical Research Service, Canada Department of Agriculture, from the original program by M. J. Garber, U.S.D.A. Users Library No. 1620-06.0.093.

⁸ Taken from the program by R. J. Daum and C. Givens, U.S.D.A. Users Library No. 1620-06.0.085.

Holding of Treated Aphids

The aphids were brushed gently into a holding cage containing a young bean plant growing in a 10.3 cm square pot. A base of unpainted fir plywood, with a slot cut to accommodate the plant stem was fitted inside the rim of the pot, on the soil. The slot was sealed with a strip of masking tape and a collar of modeling clay around the base of the plant. The body of the cage, a Kodapak cylinder 9.5 cm diameter by 18 cm high, was fixed into a circular groove cut in the plywood base, using strips of masking tape from the wall of the cage to the sides of the pot. The top of the cage was nylon organdy.

Analysis of Data

At the end of the 48 hour post-treatment holding period the aphids were counted and classified. Any aphid not capable of coordinated movement was classified as dead. The data were analysed by computer, using two probit analysis programs (Finney, 1962). The first, a single line program⁷, computed an 1d-p line for each replicate. The second⁸ also computed an 1d-p line for each replicate, then tested the lines for parallelism, computed the common slope of the regression from the pooled results, and the relative potency of each replicate.

Evaluation of the Method

The method was judged by the repeatability of the median lethal dosage (LD_{50}) and the slope estimates. Homogeneity of slope estimates is the more critical, since these indicate the variance of response to the insecticide in the treated population. The standard deviation of the slopes of the 1d-p lines, being a measure of variation attributable to the method alone (Hoskins and Craig, 1962), was also used as an indication of reliability.

Discussion

The most important factors in establishing the dosage-mortality curve were: formulation of the insecticide, and the procedures of rearing, collecting, treating, and holding the aphids after treatment. Repeatable results obtained with this method are shown by the homogeneity of the LD_{50} and slope estimates from replicate to replicate (Table 1). Figure 1 gives an 1d-p line, with 95% fiducial limits, calculated from the pooled data by Bliss' (1952) method and demonstrates the homogeneity of the data.

Various methods of exposing *A. pisum* to malathion were investigated before a suitable one was developed. During the investigation the insecticide formulation was changed and the component procedures were progressively refined.

Exposing the aphids on glass surfaces which had been sprayed with acetone solutions of malathion did not give satisfactory results. Mortality is affected by the length of time the aphid is withheld from its normal environment; and the relationships between dosage and the length of ex-

posure, and the concentration of the deposit, are not linear (Hoskins and Craig, 1962). The estimates obtained in these tests varied widely, and the standard deviations of the slopes were too large.

Solutions and emulsions were sprayed directly on the aphids in a Potter tower (Potter, 1952). Estimates of the LD_{50} were homogeneous once the procedures of rearing, collecting and post-treatment holding had been refined. Nevertheless the slopes of the 1d-p lines varied widely, and their standard deviations were still too large.

Hoskins and Craig (1962) set out 10 criteria which should be satisfied if a treatment procedure is to have general and specific applicability. These were used as guiding principles. The criteria, in descending order of importance, are: 1. constant relation of dose to dosage; 2. precise measurement of dosage; 3. quantitative evaluation of effect; 4. normality of environment; 5. constancy of environment; 6. sensitivity to variation; 7. reproducibility of results; 8. wide applicability; 9. representativity of population; 10. simplicity and rapidity.

TABLE 1. Mortality of 9-day-old *A. pisum* to which 0.5 microliter drops of actual malathion in acetone solution were applied on the abdominal dorsum. Aphids kept on live plants for 48 hours before mortality assessment. Statistics obtained by probit analysis.

Malathion ng/Aphid	Percent mortality in replicate						
	1	2	3	4	5	6	7
0	2	2	7	4	0	0	2
15	4	6	3	18	6	4	6
20	36	44	20	42	38	52	36
25	60	66	76	78	54	75	78
30	72	82	70	70	80	66	74
35	84	82	76	92	90	86	86
40	86	88	92	74	90	84	88
50	96	100	82	96	94	87	96
Statistics:							
LD 50 (ng/Aphid)	24.54	23.01	25.69	22.08	23.58	22.91	23.16
95% Fiducial Limits							
Upper	26.21	24.50	27.75	24.01	25.07	24.77	24.71
Lower	22.88	21.39	23.40	19.85	22.02	20.86	21.49
Slope	5.86	6.24	5.13	4.51	6.13	4.59	5.97
±S.E.	0.58	0.62	0.64	0.53	0.58	0.50	0.60

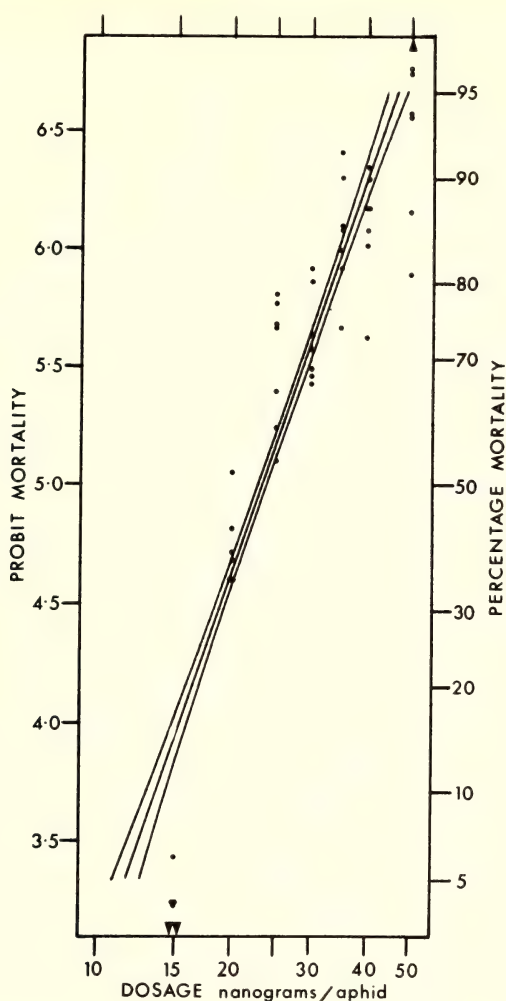


Fig. 1. Relationship between malathion dosage and mortality of *Acyrthosiphon pisum* (Harris). Bliss' (1952) method of partially weighted means was used to compute the single 1d-p line and the 95% fiducial limits. Points represent the individual observations, adjusted for control mortality, given in Table 1.

There are no means as yet to satisfy the first criterion in which dose is defined as the amount of toxicant which reaches the site of action, and dosage as the amount of toxicant applied. Neither the mode nor the site of action of the organophosphate insecticides is known. Nevertheless, the relation is measured indirectly by the standard deviation of the slope; since these values are small (Table 1), it can be assumed that the criterion is satisfied.

The eighth criterion can be satisfied only by further development. With minor modifications to suit the requirements of different species, the method developed here should be widely applicable.

The last two criteria are difficult to satisfy fully. A laboratory clone cannot represent the population because of restrictions imposed by a controlled environment and by the size of the clone; it is impossible that the total gene pool of the species be

represented. Although the method is simple, requiring little more than patience and a steady hand, it is not rapid.

The six remaining criteria are fully satisfied. Numbers 4 and 5 are of great importance because aphids are particularly sensitive to environment. Photoperiod, temperature, and population density have been shown to be instrumental in morph determination in *Megoura viciae* Buckton (Lees, 1959), *Aphis craccivora* Koch (Johnson, 1965, 1966b), and *Brevicoryne brassicae* (Linnaeus), (Lamb and White, 1966). The condition of the host plant certainly affects morph determination in *A. craccivora* (Johnson, 1966a) and probably does so in other species. Cytological studies by Uichanco (1924) on *Dactynotus* (= *Macrosiphum*) *tanacetii* (Linnaeus) have shown that ovulation begins while the mother is still an embryo. Lees (1961) states that the sex ratio can be modified by the temperature in the grandmother's environment. The morph is determined by the maternal physiology while the aphid is an embryo in its mother's ovariole (Lees, 1961) and the mother's physiology is influenced by environmental conditions to which she is subjected. The mother's or grandmother's physiological state may well influence susceptibility to an insecticide in a daughter or granddaughter.

Conditions of light, temperature, vapor pressure deficit, host plant condition, and population density were held constant from replicate to replicate and from generation to generation. The order of treatments was randomized in each replicate to avoid the possibility of an interaction of treatment time with a daily rhythm

of susceptibility, as shown for *Anthonomus grandis* Boheman by Cole and Adkisson (1964), and *Tetranychus urticae* (Koch), by Fisher (1967).

Significance of the Dosage-Mortality Curve

The average weight of the aphids used for determination of the seven ld-p lines of Table I was 4.1 ± 0.11 mg, based on seven samples of 50 aphids each. The average LD₅₀ computed was 23.5 ng per aphid, or 5.8 ug per g of body weight. This value indicates high toxicity, but comparisons with other insecticides against *A. pisum*, or with malathion against other insects, have not been possible because no reference has been found which gives the necessary information.

The slope of the ld-p line (Fig. 1) is relatively steep, indicating that there is little variation of response of the aphids to the insecticide. The probability of the aphids being able to discriminate between dosages decreases as the range of dosage is narrowed. Even though there are deviations from the computed ld-p lines, these are not truly aberrant since the dosages used to establish the lines varied within very narrow limits. The steep slope, and lack of consistent or major deviation from the ld-p lines give no indication of the presence of a pre-adapted resistance mechanism in the clone; there appears to be little chance of a resistant population developing, even after repeated selection with the insecticide.

Acknowledgments

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A SPRUCE BORER, *TETROPIUM CINNAMOPTERUM* KIRBY, IN INTERIOR BRITISH COLUMBIA

D. A. ROSS AND H. VANDERWAL¹

ABSTRACT

A spruce borer, *Tetropium cinnamopterum* Kirby, is an important borer in logs of spruce, *Picea* spp., in British Columbia. The L-shaped larval galleries penetrated to depths of 52 mm in the sapwood, and ranged from 26 to 90 mm in length; their average volume was 0.81 cc. Captive adults lived for about 2 weeks and deposited up to 155 eggs per female. Eggs hatched in about 12 days; the larvae fed under the bark for about 8 weeks before boring into the xylem of spring-felled logs. Possible control measures based on this investigation of the borer's life history and larval development are considered briefly.

Introduction

Kirby described the adult *Tetropium cinnamopterum* in 1837; Blatchley (1910) and Craighead (1923) described the larva and pupa. Craighead noted that the larvae feed only in dead trees of *Abies*, *Pinus* and *Picea* throughout eastern and northwestern North America. In studies of fire-killed white spruce, Richmond and Lejeune (1945) observed that the larvae " - - - enter the wood much as *Monochamus* do, but are shallow borers - - - average depth of penetration $\frac{3}{4}$ inch - - - ."

Marketing problems arising from borer damage (Fig. 3) and presence of living borers in the wood with subsequent degrading of lumber shipments have led to further investigations of this species at the Vernon Laboratory.

Sections of infested coniferous logs from Prince George Forest District provided numerous adult *Tetropium cinnamopterum* (Fig. 1) for these investigations. The adults were placed, usually in pairs, in small cages containing a short bolt of freshly cut spruce and some sugar solution. Adult

activity, egg incubation, larval feeding, construction of gallery and pupation were observed.

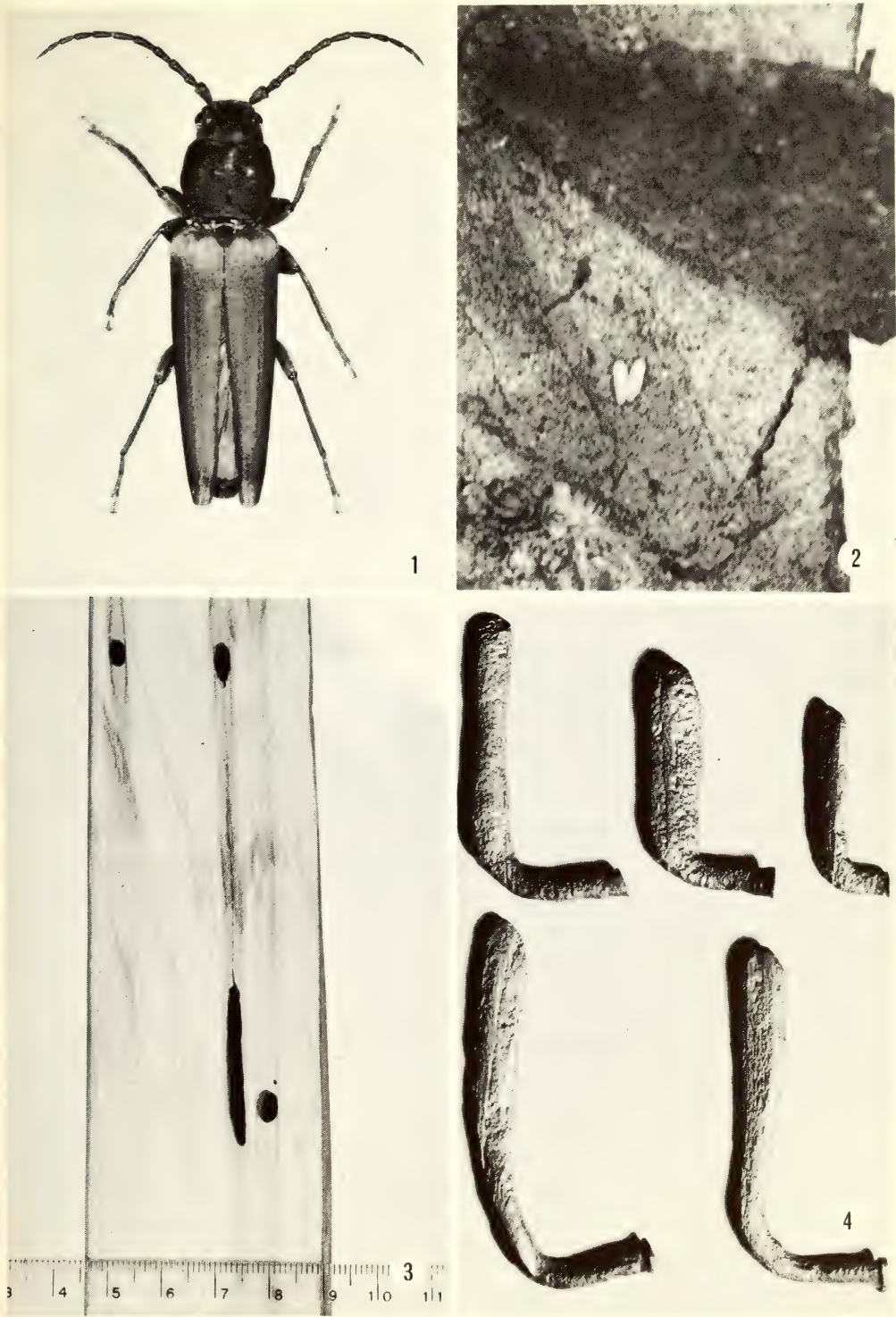
Observations

HOSTS: In the interior of British Columbia, this borer was most frequently reared from *Picea glauca* (Moench) Voss. It was also reared from several samples of *P. engelmanni* Parry and *P. mariana* (Mill.) BSP. D. Evans (pers. comm.) reared the species from *Abies amabilis* (Dougl.). Forb. in coastal British Columbia.

DISTRIBUTION: In western Canada, this transcontinental species extends northward to Mile 24 Dawson Road, Yukon Territory, south to Lumby in the northeast Okanagan Valley, and to Fernie in southeastern British Columbia (Fig. 5). Southern records are from high elevations.

ADULT ACTIVITY: Collections of perched adults from Yukon Territory and northern British Columbia were made between 27 June and 11 July. Flight traps, set up near Prince George in 1967, caught 11 adults between 16 June and 4 August, and in 1968 caught two adults, 6 June and 1 July. The emergence period of adults from caged logs collected at northerly

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Figs. 1 to 4. *Tetropium cinnamopterum* Kirby. 1, adult male; 2, two eggs under lifted scale of bark; 3, galleries in spruce board; 4, lead castings of larval galleries in wood.

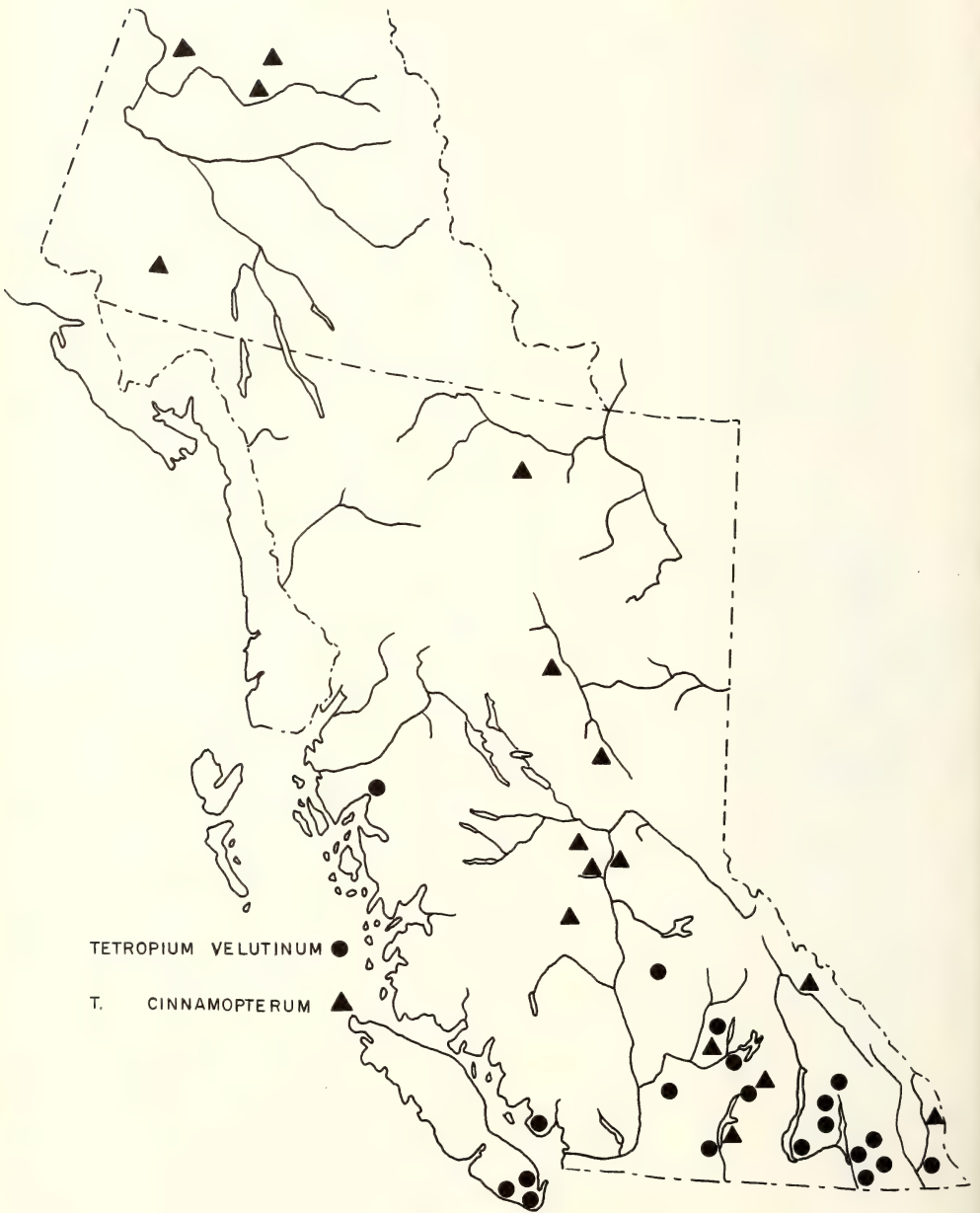


Fig. 5. Localities where *Tetropium* spp. have been collected in British Columbia and Yukon Territory.

points, and reared outdoors at Vernon, ranged from 13 May to 13 June in 1967. Average longevity of 14 pairs of caged adults was 12 days for males and 13 days for females. One male lived for 16 days and two females for 17. Copulation occurred on the day of emergence and continued sporadically for 7 or 8 days. Oviposition began 4 to 8 days after emergence.

The capsule-shaped white eggs (1.2x0.4mm) were inserted deeply between and under bark scales (Fig. 2) on the bole. One female deposited 155 eggs from 28 June to 8 July; her daily egg production was: 17, 5, 17, 17, 27, 19, 13, 0, 30, 5 and 5, respectively. INCUBATION: Eggs laid on 24 May, 1966 and kept at 70% humidity and 72°F hatched in 12 days. Two hundred eggs laid during June 1967 and placed in petri dishes in an unheated insectary incubated in 8 to 16 days, with an average period of 12 days.

LARVAL ACTIVITY: Newly hatched larvae, placed in the bark of freshly cut spruce bolts, bored into and fed under the bark for about 8 weeks before burrowing into the xylem. At that stage of development body length ranged from 15 to 23 mm; head capsule widths ranged from 3.33 to 3.83 mm.

The elliptical larval entrance holes in the sapwood ranged from 5.0 x 2.5 to 7.0 x 3.0 mm. Galleries generally were L-shaped (Fig. 4). Volumes of the completed galleries in the xylem of white spruce logs at Finlay River, B.C., ranged from 0.23 to 1.46 cc, with an average of 0.81 cc. Total lengths of galleries in the wood ranged from 26 to 90 mm, with an average of 60.2 mm. Depth of penetration varied from 12 to 52 mm, with an average of 26 mm. Galleries were densely packed behind the larvae with shreds of wood and frass, finer than that of *Monochamus* spp.

PUPATION: Duration of the pupal stage at Vernon in June 1968 ranged from 10 to 14 days.

GENERAL: The life cycle in most instances took 1 year to complete although a small proportion of some broods spent two winters in the larval stage.

The maximum recorded number of adult emergence holes in the bark was 16/ft², in a white spruce log 68 cm in diameter at the large end, from Finlay River.

Discussion

Tetropium cinnamopterum may cause damage to at least the outer 52 mm of sapwood of spruce logs since its galleries may penetrate to that depth. Its habits are somewhat similar to those of the western larch borer, *T. velutinum* LeConte (Ross, 1967), except for the host, the spruce borer's more northerly and higher altitude distribution (Fig. 5) and the resultant phenological differences.

Since the adult emergence period begins about the first or second week of June in central British Columbia, the insecticide lindane, when used on logs (Ross and Geistlinger, 1968) to kill adults or newly hatched larvae, should be applied before the egg-laying period which would begin about mid-June.

If this is not feasible, and since eggs took a week or more to hatch and larvae did not enter the wood until they were at least 8 weeks old, peeling of infested spring-felled logs before the third week of August in central British Columbia should prevent major damage to them by *Tetropium*.

It is possible that *Tetropium* larvae may enter the wood of winter-felled spruce earlier than 8 weeks.

Acknowledgment

The authors are indebted to Dr. J. J. Fettes and Mr. A. C. Molnar for suggested improvements in the manuscript.

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INSECTICIDES, FUNGICIDES AND LIME COMBINED FOR CONTROL OF CABBAGE MAGGOTS, CLUBROOT AND WIRE STEM¹

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ABSTRACT

Insecticides alone or in combinations with lime, mercurous chloride and quintozone were applied to peat and loam soils for control of clubroot, *Plasmodiophora brassicae* Wor., and cabbage maggot, *Hylemya brassicae* (Bouché), in cauliflower. The effects were assessed by counting the emergent seedlings, by weighing the mature cauliflowers, and by uprooting plants at harvest and grading the maggot damage and incidence of clubroot. Split applications, one at seeding and one 30 days later with Birlane, Dasanit or carbofuran protected cauliflower from maggot damage until harvest. Carbofuran allowed the least maggot damage in both soils. Zinophos was comparatively effective in peat soil but not in sandy loam. The insecticides had no significant effect on germination or clubroot. Quintozone gave satisfactory protection from clubroot and wire stem in sandy loam and had the lowest incidence of clubroot in peat soil. The fungicides had no effect on maggot damage, nor did they appear to influence the insecticides. No significant interactions were observed. The effect of the insecticides and fungicides on yield was somewhat masked by over-seeding.

Introduction

Previous experiments (Finlayson and Noble, 1966; Finlayson *et al.*, 1967; Freeman and Finlayson, 1968; and Finlayson, 1969) have shown that direct-seeded and transplanted cruciferous crops can be protected from maggot damage. However, fungicides and insecticides applied together have damaged crops (Finlayson, 1969 and Ranney, 1964) and when herbicides

and insecticides were applied to the same area significant reductions in yields of cabbage were recorded (Freeman and Finlayson, 1968). With the increasing cost of labor, a method for direct-seeding of stem crucifers is needed but this practice requires methods for controlling cabbage maggot (*Hylemya brassicae* (Bouché)) and wire stem (*Rhizoctonia solani* Kuhn.) in the young seedlings and clubroot (*Plasmodiophora brassicae* Wor.) throughout the growing season. Furthermore, methods and rates for

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applying herbicides must be developed to eliminate the need for hand-weeding.

Experiments were designed to determine if fungicides could be applied to reduce the amount of wire stem and clubroot infection but not interfere with the action of insecticides on the cabbage maggot. This paper reports investigations with insecticides and fungicides with and without lime, on sandy loam and peat soil in British Columbia.

Materials and Methods

The insecticides, Birlane, Dasanit, diazinon, Furadan (carbofuran) and Zinophos were selected because of their effectiveness and current or pending registration for use against cabbage maggot. Lime was used because there was a long-standing recommendation to produce a basic soil condition and thus reduce clubroot infection. The fungicides, mercurous chloride (calomel) and quintozone were selected because they are recommended, among other places, in Great Britain (United Kingdom Ministry of Agriculture, 1965), British Columbia (British Columbia Department of Agriculture, 1968), and Ontario (Ontario Department of Agriculture and Food, 1968) respectively. Quintozone has the added characteristic of reducing wire stem. Cauliflower, var. Snowball, was used because it is very susceptible to attack by maggots and to infection with clubroot and wire stem. Common names for pesticides are used in the text, but where these have not been assigned, registered names are used.

The experiment was replicated four times in sandy loam at Abbotsford and another four times in peat soil at Victoria. Each replicate was divided into six blocks representing the fungicide-lime treatments, and each of these blocks was further div-

ided into six sub-plots representing the insecticide treatments. The blocks were treated as follows: untreated; lime; calomel; calomel with lime; quintozone; and quintozone with lime. The lime, at 1500 lb/acre (1680 kg/hectare), was broadcast and disked into the soil approximately four weeks before seeding. At Abbotsford the lime was applied to the 12 blocks and randomized with three in each replicate. At Victoria high winds were such that the lime was applied to one half of the site, or 12 blocks. Calomel at 4 lb (4.5 kg/hectare) and quintozone at 60 lb (67.2 kg/hectare) per acre were broadcast and disked into the soil several days before seeding. Each of the insecticide sub-plots was a 25-foot row (7.6 m). The insecticides were applied as granules with a shaker at 2 oz (56.7 g) toxicant per 1000 ft (305 m) in a 4 inch band (10 cm) over the seeded row, and raked gently into the top inch (2.5 cm) of soil. The insecticides were reapplied as drenches of 2 oz (56.7 g) toxicant per 1000 ft (305 m) of row in 7 gal (31.8 liters), 30 days later to wet the plants and 3 inches (7.6 cm) on each side of the row.

The effects of the treatments were assessed by counting the emergent seedlings 20 days after seeding, by weighing the mature cauliflowers, and by uprooting 10 plants at harvest in each sub-plot and grading the incidence of both maggot damage and clubroot. The roots were graded as follows: no damage or clubroot, 0; light, 1; moderate, 2; severe, 3; very severe, 4.

The grades of maggot damage or clubroot for each plant were added to determine the sub-plot totals. These figures were then expressed as percentages of the maximum that could occur.

The data were coded and key-

punched, the analyses of variance calculated on a computer, and the results compared by Duncan's multiple range test (Duncan, 1955).

Results and Discussions

Germination

The average number of emergent seedlings in 25 feet of row for the insecticides ranged from 110 to 116 in peat and 107 to 116 in loam. There were no significant differences. However, when the number of seedlings was averaged within blocks for the fungicide-lime treatments the differences were significant at both locations. In peat they ranged from 103 seedlings with calomel to 121 with lime. The treatments with lime plus quintozone and lime alone had significantly more seedlings than the 110 in the untreated block. In loam the range was 106 seedlings with calomel

plus lime to 125 where only quintozone was applied. The untreated block averaged 112 seedlings. The calomel plus lime block had significantly less seedlings than the quintozone-treated block, which had significantly more seedlings than the block receiving no treatments for diseases.

Clubroot

In the sandy clay loam the percentage incidence of clubroot ranged from 8.8 to 10.0 for the insecticide treatments, and 25.8 in the plots where no lime, fungicides or insecticides were applied. When averaged across the blocks where insecticides were applied, but no lime or fungicides, the amount of clubroot was 20.5% (Table 1). The insecticides had no effect on the incidence of clubroot infection. Although the incidence of clubroot was considerably higher in

TABLE 1—Average percentage of clubroot in cauliflower after various treatments in two types of soil, 1968.

Treatment	Percentage of clubroot*	
	Peat Soil	Sandy Clay Loam
Untreated	74.5 ab	20.5 c
Lime	72.3 ab	7.3 ab
Calomel	74.5 ab	7.8 ab
Calomel and Lime	76.8 ab	13.8 bc
Quintozone	63.5 a	2.5 a
Quintozone and Lime	89.0 c	4.8 a

* Values followed by same letter are not significantly different at 5% level (Duncan, 1955).

the peat soil the insecticides did not affect the action of the fungicides nor did they lessen the amount of clubroot. Table 1 shows the effects of lime and fungicides on clubroot. Quintozone was the most effective fungicide.

Maggot Damage

In both soils carbofuran had the least maggot damage regardless of the addition of lime or fungicides (Table 2), but in the clay loam it was not significantly better than Birlane or Dasanit. In the peat soil carbofuran was closely followed by Zinophos, Dasanit and Birlane. Diazinon was only slightly better than no treatment at all. It is interesting to note

that Zinophos gave consistently better protection from maggot damage in the peat soil than in the sandy loam, regardless of the addition of the other chemicals.

Yield

In the sandy loam the effects of maggot and clubroot control are reflected by increased yields (Table 3). Blocks treated to reduce clubroot produced significantly higher yields than those untreated. For the insecticides the pattern was less definite. However, the two most effective insecticides gave yields which were significantly better than those with no insecticides.

TABLE 2—Average percentage maggot damage after various treatments to control club-root infection and maggot damage to cauliflower in two types of soil, 1968*.

Treatment		Insecticides							
Fungicides		Birlane	Carbofuran	Dasanit	Diazinon	Zinophos	Untreated	Average	
Peat Soil									
Untreated		21.3	3.8	11.3	58.3	10.0	53.3	26.3	a
Lime		10.8	7.0	10.8	37.0	7.5	43.8	19.5	a
Calomel		15.0	5.0	13.3	48.8	15.0	65.0	27.0	a
Calomel and Lime		12.0	8.8	12.5	30.8	12.5	43.3	20.0	a
Quintozone		8.3	6.3	15.0	49.5	9.5	61.3	25.0	a
Quintozone and Lime		10.8	6.3	8.3	37.0	11.3	52.0	20.8	a
Average		13.0 c	6.3 d	11.8 cd	43.5 b	11.0 cd	53.0 a		
Sandy Clay Loam									
Untreated		5.8	15.8	7.0	42.0	35.8	53.8	26.5	a
Lime		3.8	5.0	15.0	50.0	34.5	43.8	25.3	a
Calomel		6.3	3.3	8.3	38.8	20.0	42.5	19.8	a
Calomel and Lime		15.0	9.5	10.0	47.0	34.5	55.8	28.5	a
Quintozone		10.0	2.5	3.8	35.8	29.5	56.3	23.0	a
Quintozone and Lime		5.0	5.0	15.8	52.5	43.8	55.8	29.5	a
Average		7.5 c	6.8 c	10.0 c	44.3 a	33.0 b	51.3 a		

* Values followed by the same letter are not significantly different at the 5% level (Duncan, 1955).

In the peat soil the results were greater than no treatment. The effect not so clear. Quintozenone had the of treating one half of the site with highest yield but not significantly lime because of the wind and leaving

TABLE 3—Average yield of cauliflower, kg/7.6m (25 feet), after various treatments for clubroot and maggot damage in two types of soil, 1968*.

Treatment		Insecticides						
Fungicides		Birlane	Carbofuran	Dasanit	Diazinon	Zinophos	Untreated	Average
Peat Soil								
Untreated		9.8	9.9	8.5	8.8	7.8	9.2	9.0 ab
Lime		7.4	7.9	5.0	5.9	7.1	7.7	6.8 bc
Calomel		10.4	9.7	7.6	13.1	9.3	7.9	9.7 a
Calomel and Lime		6.2	6.3	5.7	7.5	5.6	6.0	6.3 c
Quintozene		9.5	10.4	10.7	11.4	10.6	10.3	10.5 a
Quintozene and Lime		7.0	7.5	7.0	6.4	6.5	7.3	6.9 bc
Average		8.4 a	8.6 a	7.4 a	8.9 a	7.8 a	8.1 a	
Sandy Clay Loam								
Untreated		6.5	6.7	5.1	5.6	6.8	5.2	6.0 b
Lime		7.4	8.9	8.5	6.9	7.9	5.6	7.5 a
Calomel		8.8	8.4	7.5	8.9	7.5	6.0	7.9 a
Calomel and Lime		8.2	10.1	7.6	9.3	9.4	5.5	8.3 a
Quintozene		10.3	9.1	7.6	8.6	8.0	8.3	8.6 a
Quintozene and Lime		8.8	9.4	8.0	8.7	7.3	9.6	8.6 a
Average		8.3 a	8.8 a	7.4 ab	8.0 ab	7.8 ab	6.7 b	

* Values followed by the same letter are not significantly different at the 5% level (Duncan, 1955).

the other half untreated showed up in the clubroot appraisal and is reflected in the yield. Although clubroot was serious on both halves of the site, the side treated with lime averaged 10% more clubroot than the side without lime. This difference was one of two contributing factors which resulted in the untreated sub-plot yield averaging 9.2 kg. It is even more apparent when the average yield for the limed and unlimed sides are compared. The average yield for the unlimed side, where the soil appeared less infective, was 9.7 kg, whereas the limed side averaged only 6.7. Differences between yields for the insecticides were not significant.

The second factor was over-seeding. The insecticides had little effect on yield because over-seeding in both soils produced on the average 113 emergent seedlings in peat soil and 114 in the sandy loam. When these were thinned to approximately 30

plants per sub-plot, the healthy, best looking plants were left and the weaker ones were pulled; thus at 4 weeks untreated plots still had approximately the same number of plants as treated plots. A count of seedlings pulled at thinning in sandy loam, revealed the relationship of maggoty-plants and plants with wire stem as follows:

Maggoty-Plants

Birlane.....	3	Diazinon	7
Carbofuran....	4	Zinophos.....	9
Dasanit	13	Untreated.....	128

Wire Stem

Untreated.....	74	Calomel	
Calomel.....	57	and lime....	32
Quintozene....	24	Quintozene	
Lime.....	52	and lime	18

By leaving healthy plants it appears that when the second generation of maggots attacked the cauliflower, the plants were big enough to produce a head in spite of the maggots.

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SYRPHIDAE COLLECTED MOSTLY IN SOUTHERN AREAS OF THE OKANAGAN VALLEY, BRITISH COLUMBIA

D. A. ALLAN¹

ABSTRACT

A list of 39 species of adult Syrphidae in 18 genera is presented with their hosts and month of capture. The specimens were collected in 1967 and 1968, mostly in the vicinity of Oliver, Osoyoos, and Mt. Kobau in the Okanagan Valley, British Columbia.

Increased interest in the biological control of orchard insects and mites in recent years has focused attention on the potential value of the Syrphidae as predators. Most of the species frequent flowers and feed on nectar and pollen so that many have a dual role as pollinators. Most of our knowledge of the Syrphidae of British Columbia is due to the efforts of R.C. Osburn. His first list (1904) contained about 80 species and his second (1907) more than 125. Subsequently, Anderson (1915) listed 7 species from the Atlin district, Venables (1929) 3 species from the Okanagan Valley, Foster (1943) 4 species from Vancouver, and Foxlee (1957) 65 species from Robson.

A survey of the Syrphidae in the

Okanagan Valley was begun in 1967 and continued in 1968 to determine the species that, in future work, might prove promising as predators and pollinators. Most of the collections were made in southern areas of the Valley near the International Boundary in the vicinity of Oliver, Osoyoos, and Mt. Kobau. Oliver and Osoyoos are situated in the Valley at about 1,000 feet (305m) above sea level; Mt. Kobau lies just to the northwest of Osoyoos at an altitude of about 6150 feet (1,876m).

Dr. J. R. Vockeroth, Entomology Research Institute, Canada Department of Agriculture, Ottawa, Ontario, identified the specimens. Thirty-nine species in 18 genera have been collected so far. These are listed alphabetically below.

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Species	Number of Specimens Collected	Place collected	Host	Date
<i>Asemosyrphus polygrammus</i> (Lw.)	1	Osoyoos	Wild flower	July
<i>Carposcalis stegna</i> (Say)	11	Osoyoos, Oliver	Dandelion, garden flower, cherry flowers	April-Nov.; mostly in May
<i>Dasysyrphus creper</i> (Snow)	2	Mt. Kobau	Dandelion	July
<i>Epistrophe grossulariae</i> (Mg.)	1	Osoyoos	Dandelion	May
<i>Eristalis arbustorum</i> (L.)	1	Osoyoos	Mustard	June
<i>E. hirtus</i> Lw.	9	Osoyoos, Oliver	Dandelion, wild flower, garden flower	July-Nov.
<i>E. latifrons</i> Lw.	1	Osoyoos	Garden flower	Sept.
<i>E. nemorum</i> (L.)	2	Oliver, Mt. Kobau	Dandelion, wild flowers	July & Sept.
<i>E. obscurus</i> Lw.	1	Oliver	Garden flower	Sept.
<i>E. tenax</i> (L.)	33	Osoyoos, Oliver, Mt. Kobau	Dandelion, golden rod, mustard, garden flower, chrysanthemum	May-Nov.; mostly in July & Aug.
<i>Eumerus tuberculatus</i> Rond.	2	Oliver	Dandelion, garden flower	May & July
<i>Eupeodes volucris</i> O.S.	51	Osoyoos, Oliver	Dandelion, mustard, white dutch clover, orchard weeds, garden flowers, water cress, bindweed, morning glory, alfalfa.	May-July, mostly in June
<i>Helophilus fasciatus</i> Walk.	2	Osoyoos, Oliver	Dandelion, chrysanthemum	May & Nov.
<i>H. latifrons</i> Lw.	7	Osoyoos, Oliver	Dandelion, mustard, garden flower	May - Aug.
<i>H. lunulatus</i> Mg.	3	Oliver	Dandelion	May
<i>H. relictus</i> (Cn. & Fl.)	1	Oliver	Water cress	June
<i>Melangyna</i> sp.	1	Oliver	Wild flower	Sept.
<i>Metasyrphus aberrantis</i> (Cn.)	5	Mt. Kobau	Dandelion	July
<i>M. lapponicus</i> (Zett.)	10	Osoyoos, Oliver, Mt. Kobau	Dandelion, cherry flowers	April-July; mostly in July
<i>M. sp.</i>	2	Osoyoos	Orchard weeds, wild flowers	June & July
<i>M. venablesi</i> (Cn.)	58	Osoyoos, Oliver, Mt. Kobau	Dandelion, mustard, garden flower, white dutch clover, bindweed, wild flowers, morning glory, sow thistle, orchard weeds, water cress	April-Aug.; mostly in May and June

Neocnemodon sp.					
Platycheirus albimanus (Fab.)	1	Penticton	Wild flower	July	
P. immarginatus (Zett.)	3	Osoyoos, Oliver	Dandelion	April & May	
P. peltatoides Cn.	1	Oliver	Dandelion	May	
	9	Oliver	Dandelion, garden flowers, pear flowers	May	
P. quadratus (Say)	1	Oliver	Mustard	May	
Scaeva pyrastri (L.)	23	Osoyoos, Oliver Mt. Kobau	Dandelion, garden flowers, mustard, bindweed, wild flowers, morning glory, orchard weeds.	Feb., June, Sept. & Nov., mostly in June & July	
Sericomyia chalcopyga Lw.	1	Osoyoos, Oliver	Wild flower	Sept.	
Sphaerophoria robusta Cn	27	Osoyoos, Oliver	Dandelion, mustard, orchard weeds white dutch clover, garden flowers, water cress	April-July; mostly in May & June	
S. sulphuripes (Thom.)	2	Osoyoos, Oliver	Dandelion, garden flower	June & Nov.	
S. sp 1	2	Oliver	Dandelion, mustard	May & June	
S. sp 2	5	Oliver	Dandelion, orchard weeds	April & May	
S. sp. 3	1	Oliver	Dandelion	May	
S. spp.	5	Oliver	Dandelion, mustard	April & June	
Syriffa pipiens (L.)	54	Oliver, Penticton	Garden flowers, wild flowers, mustard, orchard weeds, baby's breath, daisies, water cress	April - Nov., mostly in June	
Syrphus opinator O.S.	19	Osoyoos, Oliver	Dandelion, wild flowers, mustard, cherry flowers, pear flowers, grapes	April-July & Nov.; mostly in May & Nov.	
Syrphus sp.	1	Osoyoos	Wild flower	July	
S. torvus O.S.	11	Oliver, Mt. Kobau	Dandelion, mustard, wild flowers, orchard weeds, cherry flowers, apple flowers	April - Sept.	
Sylvicola marginatus (Say)	1	Kelowna	Dandelion	Sept.	

REARING THE DOUGLAS-FIR CONE MOTH, *BARBARA COLFAXIANA* (KEARFOTT), ON AN ARTIFICIAL DIET IN THE LABORATORY

D. S. RUTH and A. F. HEDLIN¹

ABSTRACT

The Douglas-fir cone moth, *Barbara colfaxiana* (Kearfott), can be reared satisfactorily in the laboratory. Methods for handling all stages and rearing larvae on a wheat germ diet are described.

Introduction

Under natural field conditions adults of the Douglas-fir cone moth, *Barbara colfaxiana* (Kearfott) (Lepidoptera: Olethreutidae) emerge in the spring when Douglas fir is flowering. The female deposits her eggs on the exposed portion of the cone bract. The eggs hatch in 2 to 3 weeks, and the larvae commence tunneling into the cone. Upon reaching the center they feed on the cone scales and seeds. By mid-July the insect has finished feeding and pupates adjacent to the cone axis.

In years when there are few cones many pupae remain in prolonged diapause for a year or more. In an attempt to obtain more information on conditions initiating diapause, *B. colfaxiana* larvae were reared in the laboratory. An artificial diet was necessary since the insects' natural food, immature Douglas-fir cones, cannot be maintained at rearing temperatures in condition suitable for the larvae, particularly in first and second instar. Use of an artificial medium allows rearing of several generations per year.

Little information is available concerning the rearing of cone insects in the laboratory. Ebel (1959) developed a technique for rearing *Dioryctria abietella* Denis and Schiffmuller (Lepidoptera: Pyralidae) in the laboratory with host cones. Artificial nutrient medium was used by Barras and Norris (1965) for rearing another olethreutid, *Eucosma*

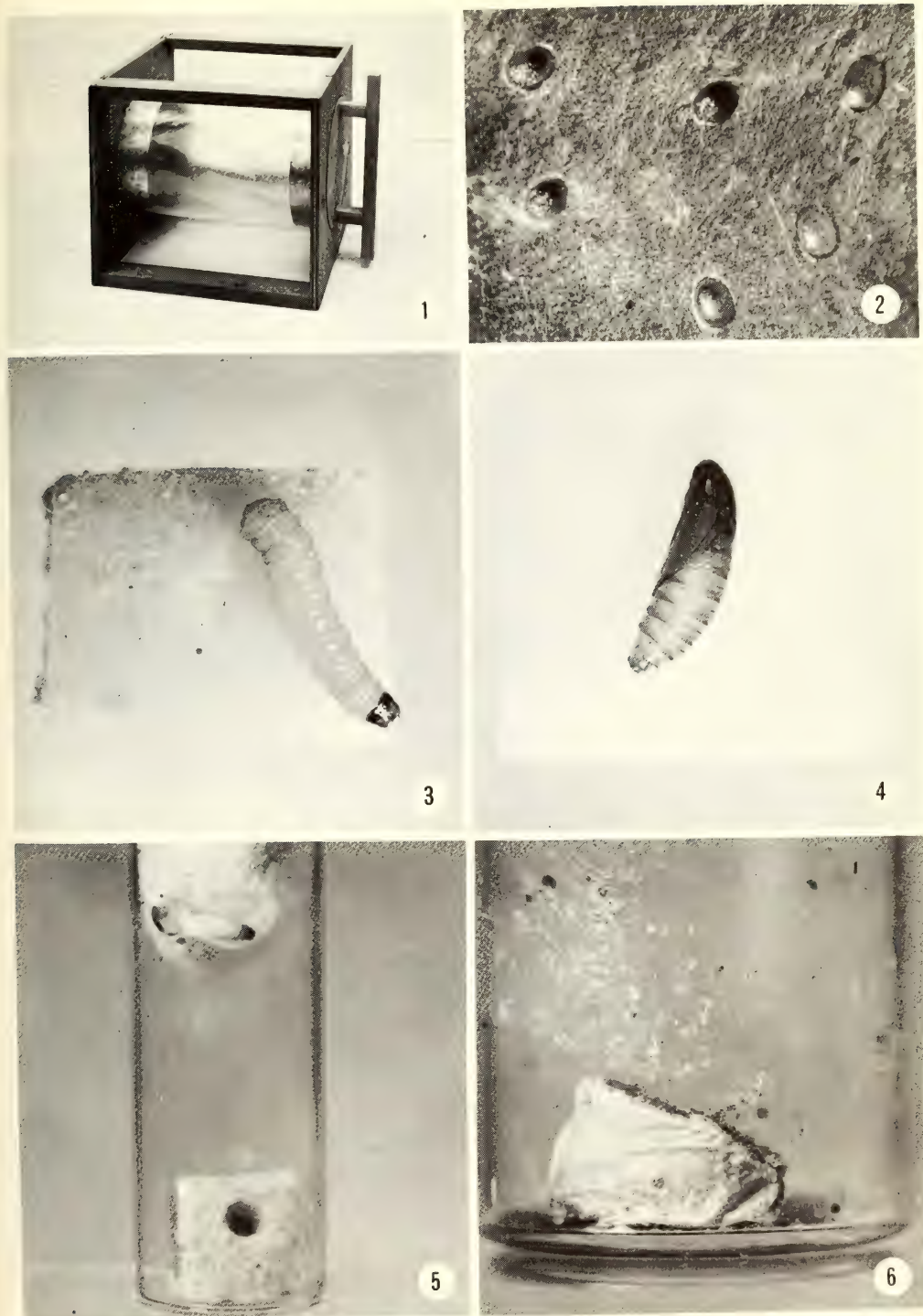
sp., from cones of *Pinus resinosa* Aiton, and Hedlin (1964) reared three species of cone insects, *B. colfaxiana*, *Laspeyresia youngana* (Kft.) and *L. piperana* (Kft.) on an artificial diet. This paper discusses in further detail the technique for *B. colfaxiana*.

Rearing Methods

Adult moths are obtained from infested Douglas-fir cones collected the previous year. Cones are stored outside until March, and then moved to a refrigerator and held at 32° F until moths are required. The cones are placed in screen cages at room temperature and emergence commences in 4 to 5 days. Twenty males and 20 females are placed in oviposition cages in an outdoor shade house to obtain field conditions for mating and oviposition. Under natural conditions mating takes place at dusk when temperature is between 50 and 65° F.

Other designs of oviposition cages were tried, but the drum-shaped cage (Fig. 1) was superior (Knott *et al.*, 1966). When cages were placed on their sides moths laid eggs at random across the upper inner surface (Fig. 2). When the eggs are nearing eclosion, determined by their orange color and visible black larval head capsules, the wax paper is removed. Small sections of wax paper with eggs are placed in a one-gallon jar with a wax paper lid. Development is observed and larvae transferred to medium soon after hatching, thus reducing mortality. Moistened cloth placed in the jar prevents egg shells

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Figs. 1-6. *Barbara colfaxiana* (Kft.) (1) Oviposition cage. (2) Eggs on inner surface of cage. (3) Fourth instar larva feeding on medium. (4) Pupa. (5) Cocoon in cotton plug. (6) Cocoon against base of vial.

from becoming hard and hindering larval emergence.

The artificial diet is the same as that used by McMorran (1965) for spruce budworm. When the wheat germ medium has been mixed and is still liquid, it is poured into 3½-inch square plastic trays which may be refrigerated until ready for use. These are stored upside down to prevent moisture collecting on the surface of the medium. When cooled and solidified, some of the medium is cut into squares, which are placed individually in the bottom of sterile one-dram vials. The vials are plugged with non-absorbent cotton and refrigerated.

In establishing larvae on the McMorran medium, a hole is punched into the block of medium and the larva placed inside to facilitate feeding. Extreme care must be exercised when establishing larvae to ensure that they are able to move freely. If stuck to the medium, they are unable to feed and soon die. The vial is stored with the plug down until the second instar, since larvae have a tendency to move upward and become entangled in the cotton plug. If first instar larvae are reared individually, the tendency to move upward is considerably reduced and vials may be stored upright. During the first instar two larvae may be placed in one vial but, because of cannibalistic tendencies which become more pronounced as the insect develops, larvae must be reared individually after the second instar.

Early larval growth is rapid. Observations made daily ensure that the medium does not become dry and trap the larva feeding in the block. Rearing at temperatures of 80° F and higher, the medium must be replaced every second or third day, particu-

larly when insects are small. The second-instar larva is in less danger of becoming trapped in or on the medium. Prior to each moult the larva spins a delicate protective case in or beside the block of medium and should not be disturbed at this stage unless there is danger of the larva becoming trapped within the medium as it hardens.

When the larva has reached the fourth and final instar, the vial is placed on its side and the block of medium moved to the center (Fig. 3). If vials are stored upright the larva has insufficient space between the vial and the block of medium in which to pupate. Some larvae will pupate without spinning cocoons, others spin against the side of the vial or on the cotton plug (Fig. 4-6).

Naked pupae are stored individually in gelatin capsules to give protection against mites and drying. The pupa is placed on absorbent cotton to prevent adherence to the side of the capsule should the capsule become damp.

At the Summerland Entomological Laboratory, a medium which consists mainly of sawdust and whole wheat flour is being used for the mass rearing of codling moth larvae.¹ The Douglas-fir cone moth belongs to the same family (Olethreutidae) and has similar feeding habits so it was thought that larvae might adapt to similar rearing techniques. However, at the temperatures in which some of our rearing was done, many first-instar larvae became trapped in the excess moisture which collected on the sides of the container and surface of the medium. Even when the larvae reached second instar, losses due to cannibalism were high.

Discussion

Difficulties associated with rearing the Douglas-fir cone moth in the

¹ Proverbs, M.D. Personal communication, Entomology Laboratory, Summerland, B.C.

laboratory are numerous. Since some female moths do not oviposit well in cages, a large number of moths must be reared to obtain a good population of larvae. Mortality is high in the larval stage, particularly in the first instar. The small larvae are unable to free themselves from the moist surface of the medium. At higher temperatures the medium dries and shrinks rapidly; young larvae are unable to feed and those tunneling inside the medium become entrapped and die. Insects will not survive if allowed to pupate beside or inside a block due to its shrinkage. Because

of these problems, considerable time and labor are required to rear an appreciable number of insects from egg to pupa. An optimum rearing temperature is about 75° F., but even under good rearing conditions only about 30% of the larvae obtained from eggs can be reared through to the pupal stage. However, our technique does allow the rearing of an insect of specialized feeding habits, under completely artificial conditions.

Acknowledgments

We thank D. Evans and L. H. McMullen, Forest Research Laboratory, for helpful criticism of the manuscript.

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BRACHYCORYNA HARDYI CROTCH AND MICRORHOPALA CYANEA (SAY), TWO HISPINAE RARE IN BRITISH COLUMBIA (COLEOPTERA: CHRYSOMELIDAE)

JAMES GRANT¹

On 12 July, 1958, I collected two chrysomelid pupae in small blotch mines in leaves of *Ceanothus sanguineus* Pursh near Wynndel, B.C. An adult which emerged 24 July, 1958, was identified as *Brachycoryna hardyi* Crotch by W. J. Brown of the Entomology Research Institute, Ottawa, who noted that there were no Canadian specimens in the Canadian National Collection.

An adult of the dark blue chrysomelid *Microrhopala cyanea* (Say) was collected 20 July 1958, on the open slopes north of St. Mary River at St.

Eugene Mission near Cranbrook, B.C., by sweeping miscellaneous ground cover. Two more adults were collected at the same locality 22 July 1959, on golden aster, *Chrysopsis villosa* (Pursh) Nutt. W. J. Brown supplied the determination. *Chrysopsis* is probably the host for this species, as an empty, inflated mine found on a leaf in this vicinity closely resembled those formed by larvae of other members of the genus in leaves of *Aster* and *Solidago*.

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OBSERVATIONS ON THE RELATION OF LIGHT TO THE DROPPING OF THE TICK *IXODES TEXANUS* BANKS

P. G. E. DARLING¹

ABSTRACT

Six ferrets were infested with large numbers of nymphs or larvae of the tick *Ixodes texanus* Banks. The animals were caged separately and subjected to various regimes of continuous light and darkness, from 9 days to 5, 4, and 2 days, and normal photoperiods. Nearly all the engorged ticks dropped from the hosts in the dark.

Introduction

When lights were unavoidably left on continuously for six days in a room where adult ticks, *Ixodes texanus* Banks, were feeding on a ferret, none detached itself. Previously four females had done so. In the 24 hrs. following a return to the normal photoperiod the remaining nine females dropped from their host. To supplement this observation tests were set up using larvae and nymphs of *I. texanus*.

Materials and Methods

Two ferrets (A & B) were infested with large numbers of larvae of *I. texanus* and placed in cloth covered cages (Kohls, 1937) under continuous artificial light. Three days later first one and later the other of these cages was enveloped in a black plastic cover (Table 1). At the end of each day when the ferrets were fed and the cloth bags were changed, the ticks that had dropped from their respective hosts were counted.

Next, two ferrets (C & D) were infested with 100 nymphs each and caged so as to eliminate differences resulting from different humidity. Both cages were covered with plastic, one clear and the other black, having light-tight baffles in the ventilation tubes. Both cages were left under continuous light, and the covers on the

cages were interchanged four times at daily then at two-daily intervals (Table 1).

Finally, to minimize the possibility of leakage or sudden intrusion of light during feeding and changing the bags, a third experiment was set up. Two ferrets (E & F) were infested with larvae, caged uniformly as before, and one of them was kept in a photographic dark room. Each evening for 10 days its infesting bag was changed in total darkness, then examined in the light.

Results

Table 1 shows the changes that were made from darkness to light, and to normal photoperiod, with the numbers of ticks collected.

Ferrets A & B showed a clear pattern of a heavy drop of ticks in continuous darkness and in alternating light and darkness, but few dropped in continuous light.

Nearly all the ticks dropped from ferrets C & D in darkness rather than in the light.

From ferret E, 95% of the ticks dropped in darkness and from ferret F 80%, even following 14 days of continuous light.

Discussion

The effects of light on the engorgement and dropping of ticks have been observed by others, and also the

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TABLE 1. Numbers of nymphs and larvae of the tick *Ixodes texanus* dropping from ferrets caged separately and subjected to light (no underline), darkness (black underline), and normal photoperiod (dotted underline).

Ferret no.	Days after infestation													Total
	3	4	5	6	7	8	9	10	11	12	13	14		
A	1	7	8	3	<u>159</u>	<u>191</u>	<u>90</u>	<u>88</u>	<u>77</u>	3	<u>421</u>	<u>65</u>	1113	
B	<u>244</u>	<u>309</u>	<u>121</u>	<u>37</u>	13	2	1	0	6	6	<u>306</u>	<u>36</u>	1081	
C	0	<u>45</u>	4	<u>13</u>	0	<u>15</u>	<u>3</u>	0	0	3			83	
D	<u>37</u>	0	<u>39</u>	1	0	<u>11</u>	<u>1</u>	0	0	0			89	
E	<u>3</u>	<u>92</u>	<u>123</u>	<u>71</u>	<u>45</u>	<u>28</u>	<u>12</u>	<u>22*</u>	8**	<u>15</u>	<u>0</u>	<u>0</u>	419	
F	0	0	0	0	1	1	4	16*	17**	<u>138</u>	<u>6</u>	<u>2</u>	185	

*Days 10 to 12

**Days 13 to 14

effect of the host's movement. Hooker (1908) noted that whereas fowl ticks drop during the night, rabbit ticks drop during the day, when the respective hosts are resting. Balashov (1954) found that the daily rhythm of dropping of engorged female *Ixodes persulcatus* from cattle appeared to be related to the host's activity. While the host was at rest in the barn, the ticks fed; while moving in the pasture, they dropped. Kheisin and Lavrenenko (1956) also observed many engorged *I. ricinus* on cattle in the morning, but few in the evening. Those noted in the evening did not drop at night if the cows remained in the cattle-yard, but fell off during the day in the pastures. If the routine was reversed so that the cattle rested during the day, the ticks would drop in the pasture at night, again suggesting that the host's activity was the cause of release.

Kitaoka (1962) found that *Haemaphysalis bispinosa* infesting cattle fed actively around midnight and dropped in the morning, regardless of the host's activity. In this case, dropping was caused by the stimulus of light, hence it was supposed that the prim-

ary factor controlling feeding and dropping was the rhythmic 24-hour change between darkness and light. George (1963) demonstrated in the rabbit tick the existence of a circadian rhythm which could be entrained by a 24-hour light cycle. In the absence of a light cycle this rhythm could be altered by changing the feeding time of the host.

From the foregoing, it seems evident that different factors govern release from the host, according to the species of tick. It appears that ticks are adapted to survive by dropping in places where they will best be able to attach later to fresh hosts. Rabbit ticks drop chiefly in the daytime when the rabbits are lying in much frequented forms (George, 1963), whereas adults of *Ixodes* cattle ticks are scattered in the pasture where their progeny may encounter rodent hosts. The observations recorded here suggest that, since the feeding and dropping of *I. texanus* may be controlled by the presence or absence of light, this tick is probably adapted to drop in the confined space of the dark holes where its hosts, the weasels, spend their resting hours.

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SCIENTIFIC NOTE

THE IDENTITY OF THE BLACK-WIDOW SPIDER IN BRITISH COLUMBIA

For many years the black-widow spider throughout North America was thought to be *Latrodectus mactans* (Fabr.). Spiders of this worldwide genus are extremely variable, and both characters and ranges overlap in many cases. It has, therefore, been difficult to establish the correct identity of its members in many localities, including our own. In 1961, Spencer reported on a study by Levi which placed our northwestern specimens

under *L. curacaviensis* (Muller).

This note is to report that Kaston (1968) after rearing cultures from all over North America, including British Columbia, has concluded that the black-widow of Western Canada and the Pacific States must be called *L. hesperus* Chamberlain & Ivle (1935), an opinion in which Dr. W. J. Gertsch of the American Museum of Natural History concurs.

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FAT CONTENT OF THE AMBROSIA BEETLE, *TRYPODENDRON LINEATUM* (OLIV.) DURING ATTACK AND BROOD PRODUCTION

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ABSTRACT

After emergence from hibernation the ambrosia beetle, *Trypodendron lineatum* (Oliv.), flies to attractive host material where it arrives with about one-half the fat it had at the start of hibernation. Analyses of beetles during attack and brood production showed a steady increase in the fat content of males, starting 5 days after the attack. The fat content of the females declined in the first 5 days, then maintained this level for about 1 week after which it rapidly increased.

Introduction

An important phase in the life cycle of the ambrosia beetle, *Trypodendron lineatum* (Oliv.), is the period after emergence from hibernation when the beetles fly and search for attractive host material in which new brood can be established (Prebble and Graham, 1957). The beetles use about one quarter of their fat in overwintering and a similar amount in the spring flight (Nijholt, 1967). This leaves about one-half of their original fat deposits when they start excavating galleries. This report deals with the fat content of beetles during attack and brood production and completes our understanding of changes during a 1-year cycle of adult activity.

Methods and Materials

The studies were carried out near Cowichan Lake, B.C. where, in April 1967, several "greenhouse" cages containing Douglas-fir logs which had been felled in Dec. 1966, provided attractant sources for *Trypodendron* (Chapman, 1966). Window flight traps (Nijholt and Chapman, 1968) were mounted on the cages to catch beetles alive during flight periods. Unattacked, equally attractive logs were exposed for 1 day during heavy flights, and samples were taken of beetles crawling on them and in flight at that time. Beetles were dug from

the logs at intervals during the following 3 weeks. All were oven dried and the fat content of groups of about 50 individuals was determined by Soxhlet extraction with petroleum ether (Nijholt, 1965).

Results and Discussion

When beetles arrive on an attractive log they crawl for a short time, presumably in search of a suitable spot to start excavating a gallery. After mating, the females dig the brood gallery and lay eggs while the males clear the boring dust from the gallery. In a few individuals the fat supply appeared to be completely depleted in the first few days after the attack. It is possible that non-ether-soluble components such as carbohydrates are then used as an energy source. However, the averaged results do not indicate a significant drop in the fat free dry weight during this period, because of the small number of beetles involved.

The proportion of fat in beetles caught during flight corresponds to that measured in the previous year (Nijholt, 1967). The percentage fat of total dry weight clearly indicates a sex difference in fat changes (Fig. 1). Student's *t* values showed significant differences in the first sample, and in those at 12, 13 and 21 days (1% level).

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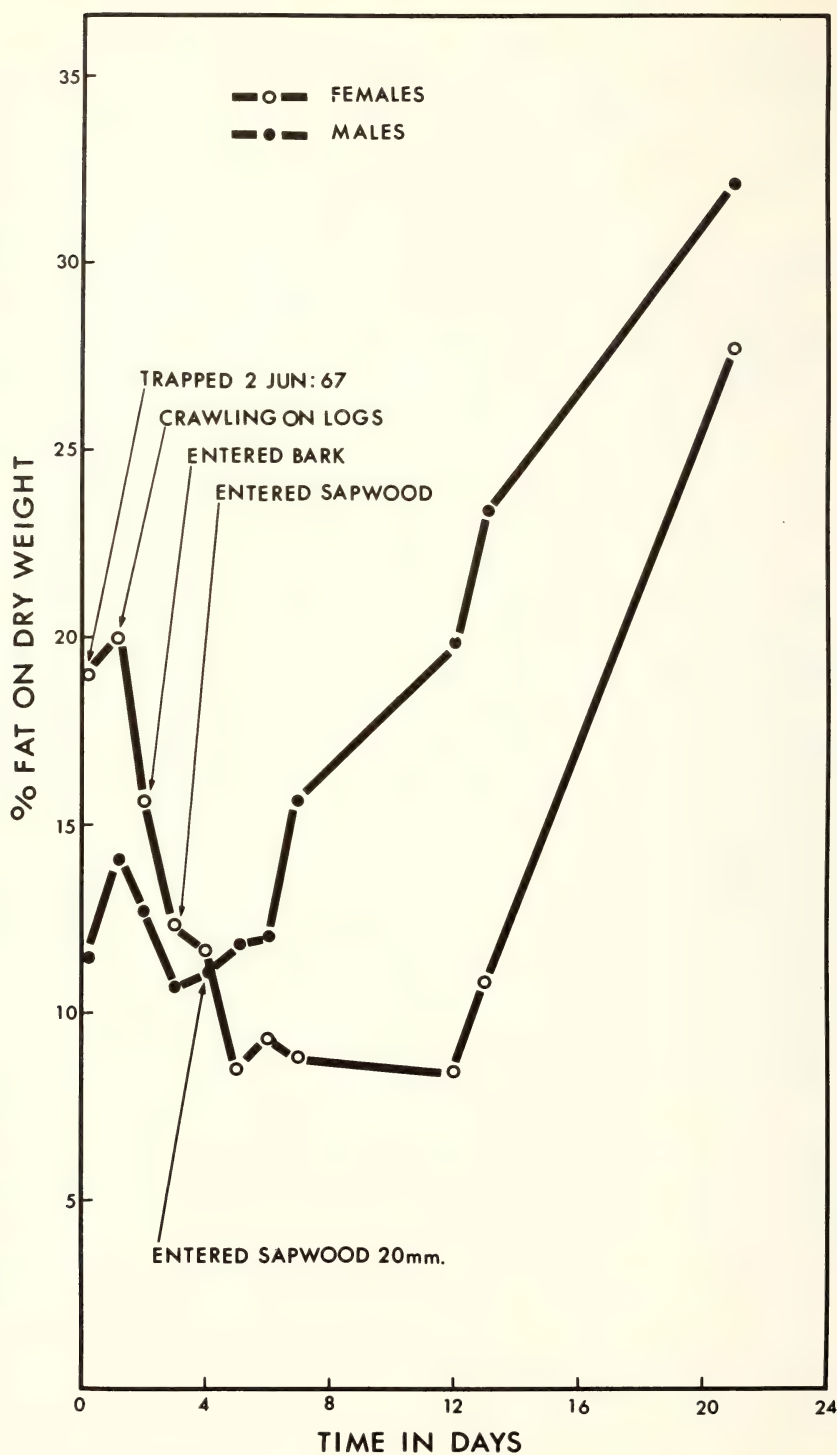


Fig. 1. Average percentage fat of dry weight in samples of 50 *Trypodendron lineatum* (Oliv.) during flight period and excavating activities.

Under the conditions of this experiment, the males steadily increased their fat content after about 5 days from attack to a three-fold level after 3 weeks. The females, needing more energy than the males for excavating and ovipositing, depleted their fat reserves by one-half during the first 5 days and then maintained this level during the next week, when they probably balanced the need for energy by feeding on fungus. Their fat content then rapidly increased, perhaps due to cessation of ovipositing, to a level slightly less than that of males at 3 weeks but equivalent to their own level at the end of hibernation. The time when feeding on fungus starts was not known and explanations for the changes in fat content are speculative.

Both sexes attain a high fat con-

tent by the time they leave the brood logs, enabling them to go through another attack and brood establishing phase or into hibernation. Previous data indicated that on a dry weight basis the females can reach a level of about 40% fat content compared with 30% for males.

The data from this and earlier studies give a general understanding of fat changes during the adult life of this beetle and provide a basis for comparison of fat values in beetles sampled in the natural environment. They also form a basis for a study of the qualitative aspects of fat metabolism in these insects.

Acknowledgments

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ERRATUM

In Vol. 65, page 4, column 2, paragraph 1, on the 10th line from the top of the page ": . . . 65c per animal per year." should read ". . . 6.5c per animal per year."

THE DISTRIBUTION OF TWO SPECIES OF *CENOCORIXA* IN INLAND SALINE LAKES OF BRITISH COLUMBIA

By G. G. E. SCUDDER¹

ABSTRACT

The distribution of *Cenocorixa bifida* (Hung.) and *C. expleta* (Uhler) in British Columbia is summarized. The distribution pattern in a series of inland saline lakes in the central interior of the Province is described. All water bodies are in the flight range of the two species, and seem to be colonized by them at random. However, *C. expleta* occurs and breeds only in saline waters, whereas *C. bifida* lives and breeds in fresh and moderately saline environments. *C. expleta* has been found only in waters with a conductivity between 3,900 and 29,000 micromhos/cm. (at 25°C): *C. bifida* occurs only in waters with a conductivity between 20 and 20,000 micromhos/cm. The distribution appears to be correlated with salinity and not with other features of the environment such as area of water body, mean depth, maximum depth, etc.

Seven species of *Cenocorixa* are recorded from British Columbia (Lansbury, 1960), but little is known about their distribution, abundance and biology. A comparative study has been started on two of the species *C. bifida* (Hung.) and *C. expleta* (Uhler). This paper describes the distribution of the two forms in the province of British Columbia, and further considers their occurrence in a series of saline water bodies in the Southern Interior Plateau region.

Materials and Methods

The general distribution of the species in the Province was determined from published records, from specimens in the Spencer Entomological Museum at the University of British Columbia and from personal collecting. Climatic data were taken from the B.C. Resources Atlas (Chapman *et al.*, 1956).

In the study of the lakes in the Southern Interior Plateau, a general survey was carried out in the period 1958-1960, and in 1961 a series of water bodies was selected for intensive study. The lakes were chosen so as to obtain as wide a range of salin-

ity as possible, after the initial survey indicated that this was desirable. Those selected were chosen so that many other parameters of the environment were alike. Thus all water bodies were situated in the same general geographic area, on approximately the same latitude and longitude, were around 1000 m elevation, were situated in open grassland, were without fish as predators, but had cattle access and so were subject to disturbance and pollution.

The water bodies selected for special study are located in the Chilcotin and Cariboo Parklands biotic areas, but one lies within the Dry Forest area of Munro and Cowan (1947). Those named as lakes, e.g. White Lake, are to be found on maps. The others have local names or names used only in this project. Most are on Beecher's Prairie, just north of Riske Creek (Fig. 1). Others are distributed as follows: Westwick Lake, Boitano Lake and Rush are between Williams Lake and Springhouse, with the locality Sp. 6 a little way beyond Springhouse on the Alkali Lake road. White Lake and Long Lake are on the road between Clinton and Gang Ranch, the locality GR2 being about 10 miles west

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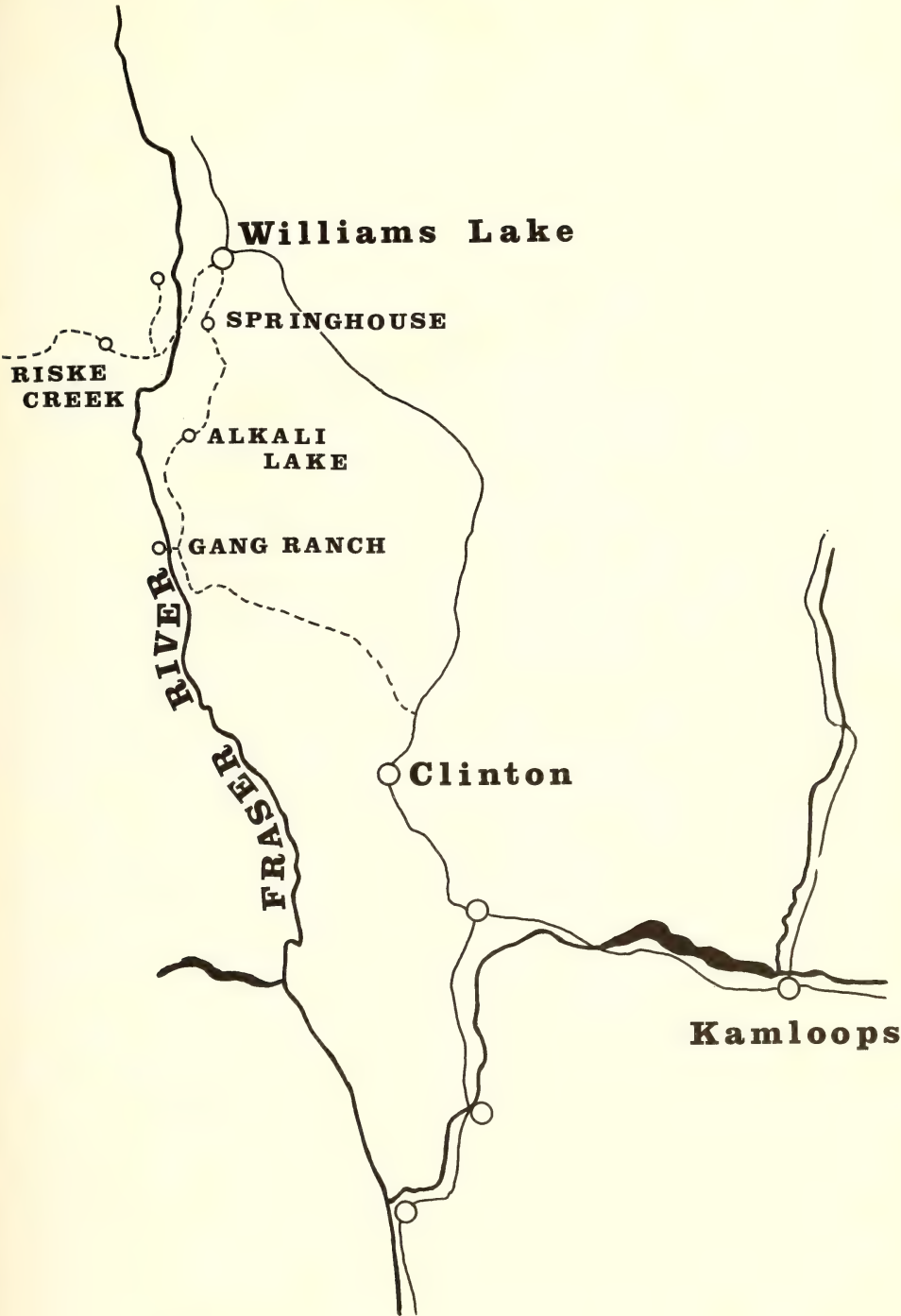


Fig. 1. Map of the Southern Interior Plateau region of British Columbia, showing localities mentioned in text.

of the Highway. Finally, the water body called LB2 is adjacent to Lac du Bois, near Kamloops, (Fig. 1).

In all 20 lakes were included in the detailed study, the physical and chemical limnology of which will be described elsewhere (Topping and Scudder, in prep.). Faunal samples were obtained from each habitat at approximately monthly intervals during the ice-free period from April to November, in the years 1958-1968 inclusive. At the same time, water temperature and surface conductivity were measured using a Yellowsprings Portable Solubridge: pH and conductivity were also measured in the laboratory using Radiometer apparatus.

Information on dispersal was obtained by the use of light traps and horizontal reflection traps of the type described by Fernando (1958). These were set up adjacent to Westwick Lake and the Corixidae captured were noted.

The behaviour of insects in waters of varying salinity and temperature was observed in the laboratory. Insects were placed in 250 ml beakers containing 150 ml of water of known salinity. Experiments were carried out in constant temperature cabinets at 5°C, 15°C and 25°C. Each beaker was contained in a covered plastic box. The number of insects leaving the beaker and found in the box was recorded.

Results

1) General distribution

Fig. 2 summarizes in a general manner, the known distribution of the two species in British Columbia. Records available are as follows: new locality records are in italics.

Cenocorixa bifida (Hung.): Peachland, Vernon, Oliver, Nulki L., Kamloops, (Hungerford, 1948). Chilcotin, Nicola, Malahat, Ver-

non, 6 mi. S. Clinton, 149 mile L., Soda Cr., Milner, Westwick L., Riske Cr., Boitano L., Peachland, Nulki L., Westbank, Summerland, Oliver, Hope Mts., Jesmond, Minnie L., Nicola (Lansbury, 1960). McIntyre L. (Scudder, 1961). Horsehoe L. (Sparrow, 1966). *Lyons L.* (G. Halsey); *White L.* (G. G. E. Scudder); *Long L.* (G. G. E. Scudder); *Doctor's L.* (G. G. E. Scudder); *Pavilion L.* (G. G. E. Scudder); *Beaverdam L.* (G. G. E. Scudder); *Bower's L.* (G. G. E. Scudder).

Cenocorixa expleta (Uhler): Kamloops, 6 mile S. Clinton, Riske Cr. (Lansbury, 1960). *White L.* (G. G. E. Scudder); *Long L.* (G. G. E. Scudder); *Bower's L.* (G. G. E. Scudder); *Lyons L.* (G. Halsey).

Superimposed on this map is the area of the province that has a mean annual precipitation of around 43.5 cm, (15 in.), and in which the known saline lakes in the province are situated. It is seen that in general the records of both species lie within this climatological boundary.

ii) Detailed distribution

Table 1 lists the water bodies selected for special study and summarizes the most important environmental data required for the present discussion. It also shows in a general manner, the occurrence of the two species of *Cenocorixa*. *C. bifida* is found in waters with a mean surface conductivity between 38.6 and 14,848 micromhos/cm (at 25°C), while *C. expleta* has a narrower range. In British Columbia the two species have been found sympatric in ten water bodies, six of which are listed in Table 1. Allopatric populations of *C. bifida* occur in the fresh waters, while to date no allopatric population of *C. expleta* has been discovered. The data show no obvious correlation of distribution of the species with water body

Water body	Area (ha)	Mean depth (m)	Max. depth (m)	Mean surface conductivity (microhms/cm at 25°C)	Mean surface pH	Main cation	Main anion	Cenocorixa bifida	Distribution Cenocorixa expleta
GR2	15.35	0.8	1.5	42,590	10.15	Na	CO ₃	-	x
LB2	3.08	1.1	2.5	14,848	9.63	Na	CO ₃ -SO ₄	o	*
Long L.	33.50	2.2	4.5	12,388	9.41	Na	SO ₄	ø	*
Box 4	17.20	2.0	4.5	10,473	9.50	Na	HCO ₃ -CO ₃	*	*
Phalerope	30.84	2.6	6.2	6,883	9.31	Na	HCO ₃ -CO ₃	*	*
Box 20-21	46.50	2.8	5.4	6,074	9.30	Na	HCO ₃ -CO ₃	*	*
White L.	127.68	5.0	15.5	5,540	9.50	Na	HCO ₃ -CO ₃	*	*
Boitano L.	80.70	2.7	4.5	4,728	9.00	Na	HCO ₃ -SO ₄	*	-
Rush	19.59	1.1	2.5	3,994	8.74	Na	HCO ₃ -SO ₄	*	-
Nr. Op. Box 4	5.83	1.4	2.3	3,231	8.81	Na-Mg	SO ₄	*	-
Box 89	15.18	1.0	2.3	1,803	9.08	Na	HCO ₃	*	-
Rock	34.60	1.1	2.5	1,698	9.21	Na	HCO ₃	*	-
Westwick L.	58.32	1.3	4.5	1,515	8.72	Mg	HCO ₃ -CO ₃	*	-
Nr. Phalerope	5.06	1.3	3.0	1,457	8.64	Na	HCO ₃	*	-
Nr. Op. Cr.	6.88	1.4	3.3	827	8.98	Mg	HCO ₃ -CO ₃	*	-
Box 17	2.67	1.1	3.3	782	9.00	Mg	HCO ₃ -CO ₃	*	-
Op. Box 4	4.53	0.7	2.2	720	9.27	Mg	HCO ₃ -CO ₃	*	-
Racetrack	27.03	1.9	6.5	541	8.52	Na	HCO ₃	*	-
Sp. 6	0.85	0.6	1.5	254	8.80	Mg	HCO ₃ -CO ₃	*	-
Box 27	4.30	0.5	1.5	38.6	6.86	Mg	HCO ₃ -CO ₃	*	-

Table 1. List of water bodies studied with certain environmental data plus the distribution of *C. bifida* and *C. expleta*: * = one or two generations produced each year; o = first generation produced, but second unsuccessful; ø = first generation produced, second generation successful only some years; x = overwintered adults recorded, but no breeding detected in these waters; - = species never taken in these water bodies.

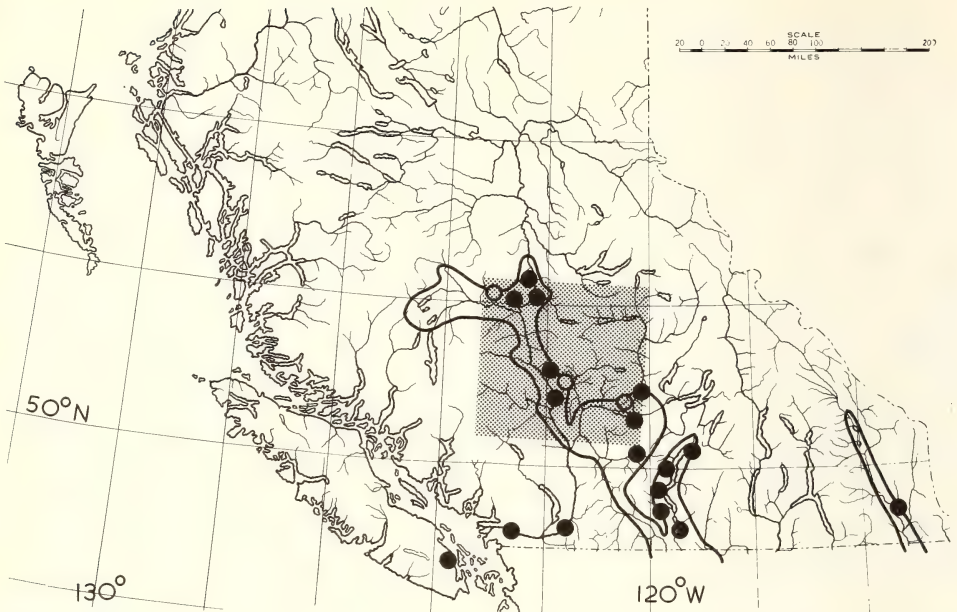


Fig. 2. Map of the southern half of British Columbia showing the known distribution of *Cenocorixa bifida* (closed circles) and *C. expleta* (open circles). Solid line shows area with a mean annual precipitation of 43.5 cm. or less, and stippled region represents area covered in Fig. 1.

area, mean depth, maximum depth, pH, main cation or main anion; there is a correlation with conductivity.

iii) Temporal changes in the distribution.

Comparisons have been made of the detailed distribution of the two species in the above lakes, comparisons being made of the patterns of distribution for spring, summer and fall for each of the ten years 1958-1968. While there has been no substantial change in the occurrence of the species in the lakes at the lower end of the salinity range, this is not the case at higher salinities. Here the distribution of *C. expleta* and *C. bifida* varies with seasonal and annual changes in surface conductivity of the water. There may be a three-to four-fold change in surface conductivity during any one year, and a two-to three-fold change from year to year. At times of substantial change, there

occur changes in the distribution of the breeding populations of *Cenocorixa*.

Seasonal changes in distribution can be illustrated by considering the occurrence of the two species in the two localities Long Lake and LB2. Each year overwintered adults of both species occur in Long Lake and LB2. LB2 on 23 May 1966 had a surface conductivity of 9080 micromhos/cm. at 15.5°C and on 5 May 1968 the conductivity was 4680 micromhos/cm and the temperature 11°C. A first generation of larvae was produced in both species in the spring of the years 1966 to 1968, but while *C. expleta* was able to produce a second or summer generation in this habitat, this apparently did not occur in *C. bifida*. Larvae of the latter were not found in the LB2 locality in mid summer in any of the three years, a time when the conductivity had risen considerably. Thus both species are present in the spring,

but only *C. expleta* occurs in this water body in middle and late summer: the habitat is evidently recolonized each fall by *C. bifida* from neighbouring less saline habitats.

Similarly, in 1963, Long Lake like most of the other water bodies in the area at this time, had a conductivity well above the average. In May 1963 a first generation of *C. bifida* and *C. expleta* was produced with the conductivity at 13,200 micromhos/cm at 8°C. In the summer of 1963, there was a second generation of *C. expleta* reared, but not of *C. bifida*. The conductivity at this time had risen to 27,260 micromhos/cm at 22°C. Thus in 1963, and indeed in the previous two years, *C. bifida* appeared to die out in the Long Lake habitat in the summer and recolonize the lake in the fall, similar to LB2 above.

However, in the past few years there has been a marked change in the salinity of the most concentrated waters. This has evidently been due to

the relatively colder and wetter years since 1963 and in the Long Lake locality also, attempts by a local rancher to divert a neighbouring creek into the lake and use the water for irrigation purposes. Thus in Long Lake in 1966, the water level was higher and the conductivities lower than in the period 1961-1963. These salinity changes have been accompanied by changes in the distribution pattern of the Corixidae. Instead of *C. bifida* in this habitat producing only a spring generation and then dying out as in 1963, in 1966, 1967 and 1968 this species produced both a spring and a summer generation similar to *C. expleta*. At no time in these three years did the surface conductivity in Long Lake go above 12,000 micromhos/cm at 25°C. Thus in these years there was a distribution pattern that differed from previous years.

We have not found any Corixidae breeding in the water body GR2 and so assume that they cannot do so.

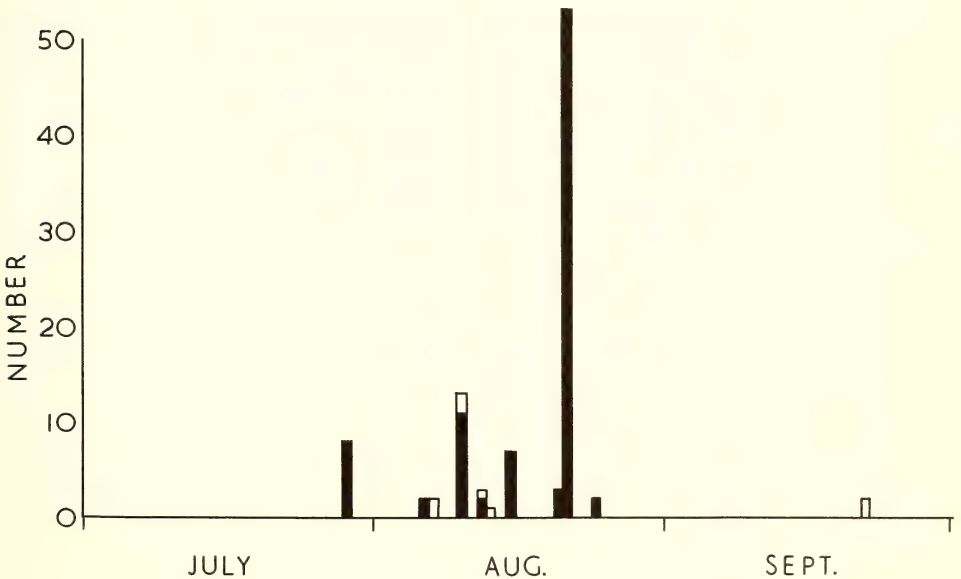


Fig. 3. Diagram showing flight period of *Cenocorixa bifida* in Westwick Lake area in 1964 (Data from Simpson, 1968). Solid columns represent light trap captures; open, horizontal reflection trap captures.

However, on 3 May 1964 a single female *C. expleta* was captured swimming in the water, and so the lake is not outside the flight range of the species.

iv) Dispersal of Corixidae

In an attempt to obtain some information on the dispersal of these Corixidae, light traps and horizontal reflection traps were run through the season at Westwick Lake. The results of this trapping are shown in Fig. 3. Flying *C. bifida* were taken between July 28 and September 25. A single female *C. expleta* was also taken on 12-13 September 1964. These results show that *C. bifida* has a pronounced tendency to disperse in late summer and fall: this is the time that adult insects are found to reappear in such saline waters as LB2 and further, at this time the water temperature also is beginning to drop.

v) Flight behaviour of *C. bifida* in waters of various salinity and temperature.

Experiments were carried out with natural lake water of varying salinities: the experimental temperatures were 5°C, 15°C and 25°C, the lower temperature approximating the normal environmental temperature in early spring, 25°C being around the highest temperature recorded in the study area in the summers.

A standard one hour period was used for each experiment, 20 insects being used in each test. The results (Table II) show that *C. bifida* has a pronounced tendency to leave water at a temperature of 25°C. Such behaviour was less evident at 15°C and was not seen at 5°C. There was little difference with waters of different salinity.

Discussion

The records in the literature and the detailed study of the two species of *Cenocorixa* in British Columbia indicate that they both generally occur in areas with a mean annual precipitation of under 43.5 cm (15 inches). In the area studied *C. expleta* occurs only in saline waters, whereas *C. bifida* lives and breeds only in fresh and moderately saline water. *C. expleta* has been found only in waters with a conductivity between 3,900 and 29,000 micromhos/cm (at 25°C). *C. bifida* was taken only from waters with a conductivity between 20 and 20,000 micromhos/cm.

Elsewhere within the range of these species, they appear to occur in similar relatively dry areas. *C. bifida* has a wider range than does *C. expleta*, the latter being confined to western North America (Hungerford, 1948). *C. expleta* seems to occur in saline water also elsewhere (Brooks

TABLE II. Proportion of *C. bifida* (flying form) leaving waters of different salinity and temperature in one hour

Source of Water	5°C		15°C		25°C	
	Conduct	% leaving	Conduct	% leaving	Conduct	% leaving
Sp.6	16.2	0	21.6	0	27	35
Boitano L.	438	0	584	0	730	35
White L.	2,850	0	3,800	10	4,750	40
Long L.	7,320	0	9,760	5	12,200	40
GR2	19,800	0	26,400	0*	33,000	30**

* 15% died in water

** 20% in addition died in water

& Kelton, 1967). Edmondson (1966) reports *C. expleta* from Soap Lake in the Grand Coulee area of Washington, and this has a surface TDS of between 21,200 and 37,112 ppm. He notes that in the years since the salinity has started to go down due to irrigation projects, *C. expleta* has become much more abundant than formerly when the salinity was high. I have also taken *C. expleta* together with *C. bifida* from the adjacent Lenore Lake on 23 March 1968 when the conductivity was 2899 micromhos/cm (at 25°C). Similarly, Hungerford (1948) records *C. expleta* from Redberry Lake in Saskatchewan. This lake is saline and according to Rawson & Moore (1944) has a TDS of 13,000-14,000 ppm.

The field results suggest that the two species differ in their salinity tolerance. The fact that *C. bifida* was eliminated from Long Lake in the years 1961 to 1963 and from LB2 over the years this water body has been studied, indicates that there is a certain upper lethal combination of temperature and salinity for *C. bifida*. There must be a similar upper lethal level for *C. expleta*, but no lake among those studied, attained this level. The upper level for *C. expleta* would appear to be higher than that for *C. bifida*, but must be below the levels that exist in GR2.

The fact that both species have been obtained in terrestrial trapping research and the fact that *C. expleta* has been taken in GR2 alive, shows that the species have an innate tendency to disperse, something that has been noted for other Corixidae (Macan, 1939, 1962; Fernando, 1959; Johnson, 1966). Since the water bodies are in the same general area, one can assume that they are all potential environments for these two insects. On the Beecher's Prairie area with the many lakes close together, it

would be difficult to deny that all of the water bodies are potential habitats for *C. expleta*, yet it has been found only in four of the twenty or more larger habitats located there. Further, since the species are attracted to the shiny surface of the horizontal traps, they must be attracted at random to any shiny surface. Presumably they are thus attracted to all bodies of water, randomly, irrespective of their other characteristics.

Laboratory experiments have shown that *C. bifida* (and presumably also *C. expleta*) tend to fly from water when it is at 15°C or above: the higher the temperature, the greater the flight response. The species cannot survive more than one-half hour at 30°C and above, and live for a few days only at 25°C. These lethal temperatures evidently are related among other things to the transition point of the cuticular waxes, which for *C. expleta* is 29.5°C (Oloffs and Scudder, 1964). While the insects tend to leave waters at a temperature above 15°C, they rarely take flight at lower temperatures. Even when they are placed in water salinities that are lethal, they do not attempt to leave.

This suggests that once an insect lands in a body of water, provided the temperature is below 15°C, the insect will remain and not leave; presumably since most water bodies have areas that are cool even when surface waters may be warm, the insect will tend to remain once it enters them. Thus all waters would seem to have an equal chance of colonization at the time of random dispersal.

Studies on two other Corixids *Callicorixa audeni* (Hung.) and *Hesperocorixa laevigata* (Uhler) have shown that these have a flight period that coincides in time with that in *C. bifida* (Simpson, 1968). Further, these two species are known to colonize most water bodies each fall, but rare-

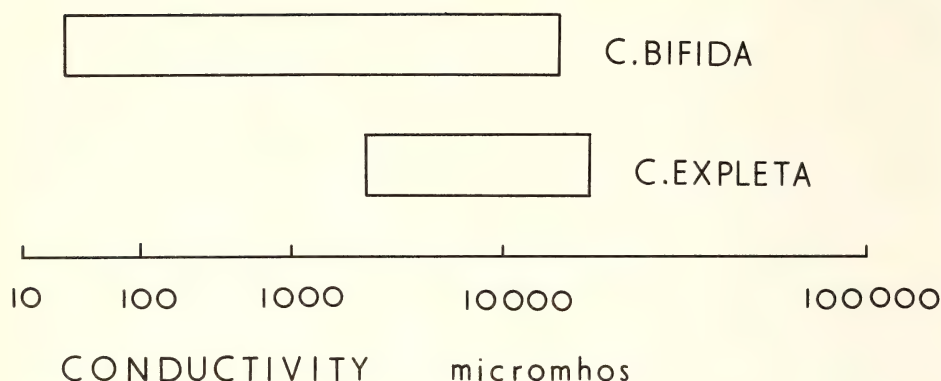


Fig. 4. Diagram showing field distribution of *Cenocorixa bifida* and *C. expleta* in British Columbia, with respect to the conductivity of the environment.

ly do they breed in them in the succeeding year (Scudder, 1969). All of the water bodies in the area have an equal chance of colonization by Corixidae.

Thus the distribution of the two species of *Cenocorixa* in the inland saline lakes in central British Columbia seems to depend on the species tolerance to the salinity, and is not clearly correlated with other characteristics of the habitats; the species' food appears to be the same. The two species occur in the same area, but

have different salinity ranges, although they do overlap.

Fig. 4 summarizes the findings with respect to this correlation of distribution and the conductivity of the environment. The species appear to differ quite markedly. Only experimental studies will reveal the basis for these differences in tolerance, survival and distribution.

Acknowledgments

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INFLUENCE OF TEMPERATURE INVERSION ON DEVELOPMENT OF SPRUCE BEETLE, *DENDROCTONUS OBESUS* (MANNERHEIM) (COLEOPTERA: SCOLYTIDAE)

By E. D. A. DYER¹

ABSTRACT

In the East Kootenay region of British Columbia, spruce logs infested by *Dendroctonus obesus* (Mannerheim) were placed beside thermographs at three sites. Throughout the summer, the mean and minimum air temperatures were higher on a mountain slope than in two valley bottoms at similar or lower elevations. Beetle development was faster on the mountain slope, where it continued until frost occurred in October, at which time 96% of the progeny were mature. In the lower valley bottom the minimum temperature fell 3.9 and 2.8°C (7 and 5°F.) below freezing on successive nights in August and larval development stopped. In the valley bottoms only 13 and 9% of the broods matured before winter. Temperature conditions that allow most broods of *D. obesus* to mature in one season may result in a critical addition to the normal number of beetles that mature after 2 years' development.

Introduction

Dendroctonus obesus (Mannerheim) is the most destructive bark beetle of mature spruce forests (Swaine, 1924; Woods, 1963). Endemic populations breed in wind-thrown trees and logging slash, but when the population is large the beetles frequently attack and kill the largest trees over extensive areas (Swaine, 1924; Massey and Wygant, 1954).

In spruce forests growing at northern latitudes and high elevations most spruce beetles require 2 years to reach maturity, but during hot summers and in warm locations many of the young mature in a single season (Watson, 1928; Massey and Wygant, 1954; Knight, 1961). In western North America, only the beetles that have passed the winter as adults reproduce the next summer (Massey

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and Wygant, 1954; Knight, 1961). The developmental rate therefore, has a direct effect on the number of adults capable of invading new hosts the following year.

Methods

The Agroclimatology Sector of A.R.D.A. (Agricultural and Rural Development Act Administration of Canada) has recently taken thermograph records at several locations in the Rocky Mountain trench in south-eastern British Columbia.

Three locations were near spruce forests and accessible when the *D. obesus* flight began in early June 1967. Site A (4,700 a.s.l.) was on a mountain slope, about 2,000 feet above the valley. Site B (3,500 a.s.l.) was approximately 50 miles to the north in a valley bottom. Both sites were adjacent to the Rocky Mountain trench near the source of the Columbia River. Site C (4,600 a.s.l.), another valley bottom, was in the Flathead River drainage near the Alberta border.

Six recently - cut 30 - inch - long spruce logs were placed on the ground in the shade of scattered small trees near the thermograph at each site. The instruments were in Stevenson screens in cleared areas.

On 5 June, beetles had entered the bark of logs moved on that date from a nearby valley to site A. One of these logs was placed as a control with uninfested logs at site B, where natural beetle attack was observed the same day. Uninfested logs were placed at site C on 6 June.

Samples of bark were removed from the logs at sites A and B on 23 and 24 August, respectively. Larvae, pupae and young adults were counted, and the larvae individually measured to determine their stage of development. Site C could not be reached at that time. On 18 October, the broods in logs from all three sites

were examined to determine the degree of development for the season. An index of development was calculated from these samples, in which 100% eggs equalled 100, and 100% young adults equalled 700.

Results and Discussion

The minimum temperature for spruce beetle brood development has been determined in laboratory studies to be approximately 43° F. The accumulated degree-hours air temperature above this threshold, plotted each 2 weeks for sites A and B, are shown in Fig. 1 along with the index of development.

The mean and minimum temperature was consistently warmer at site A on the mountain slope, than at site B in the valley bottom (Figs. 1-2). Such summer temperature inversions in this mountainous region are common; Hayes (1941) has shown that inversion occurred on 90 to 99% of nights from May to September during 4 years in Idaho. The median magnitude of night temperature difference between the colder valley bottom (2300 a.s.l.) and the warmer mountainside (3800 a.s.l.) was 9° to 18°F in May and June, respectively, and 15° to 18° from July to September.

Brood development at sites A and B, as shown by the index (Fig. 1), proceeded at a rate parallel to that of the respective accumulated degree-hours at each site until late August. After this the temperature accumulation rate declined at both sites. At site A the brood continued to develop at a reduced rate until nearly all reached maturity, whereas at B, development almost stopped at the end of August and most of the brood overwintered as larvae.

A possible explanation for the difference in development during the latter part of the season is illustrated in Fig. 2. The maximum temperatures throughout August and September

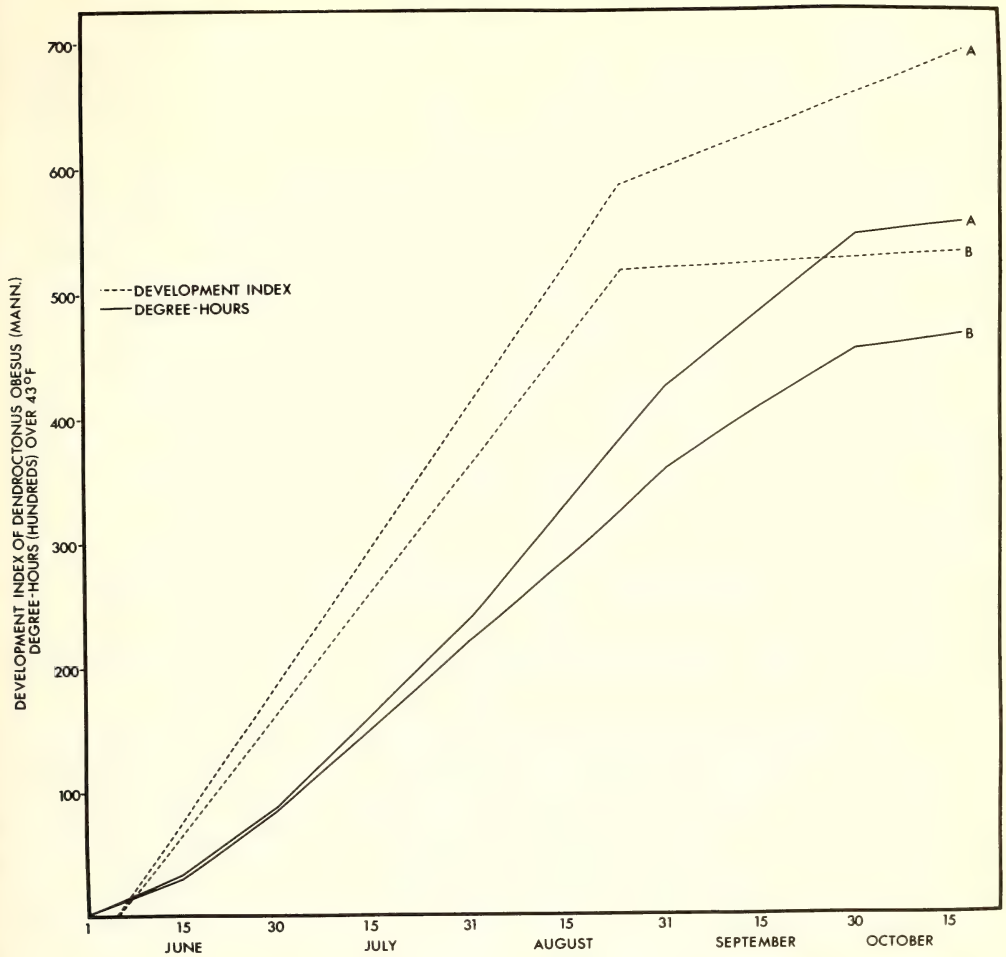


Fig. 1. Index of brood development and accumulated degree-hours above 43°F. (6.1°C) from 1 June to 18 October, 1967, at site A, on a mountain slope and at B, in a valley bottom.

were about the same at sites A and B, but the minimum temperatures were much higher at A. At B they dropped 5° and 7°F below freezing on successive nights in late August. At site A no frost occurred until mid-October.

The percentages of fourth-instar larvae, pupae and adults in samples collected in August and October from the logs at sites A and B are shown in Table 1. At site A both larvae and pupae continued to mature and 96% became adults by October. At site B, the percentage of larvae remained almost the same from August to Oc-

tober, although the pupae completed development.

At site C, the mean temperature was consistently lower (1-4°F) than at site B for every 2-week period from June to October. However, the minimum temperature in August was 3°F higher than at site B. By October, the brood development at site C was nearly the same as at site B (Table 1). Larval development at site C, although slower, was possibly not terminated so early as at site B where lower minimum temperatures occurred in late August.

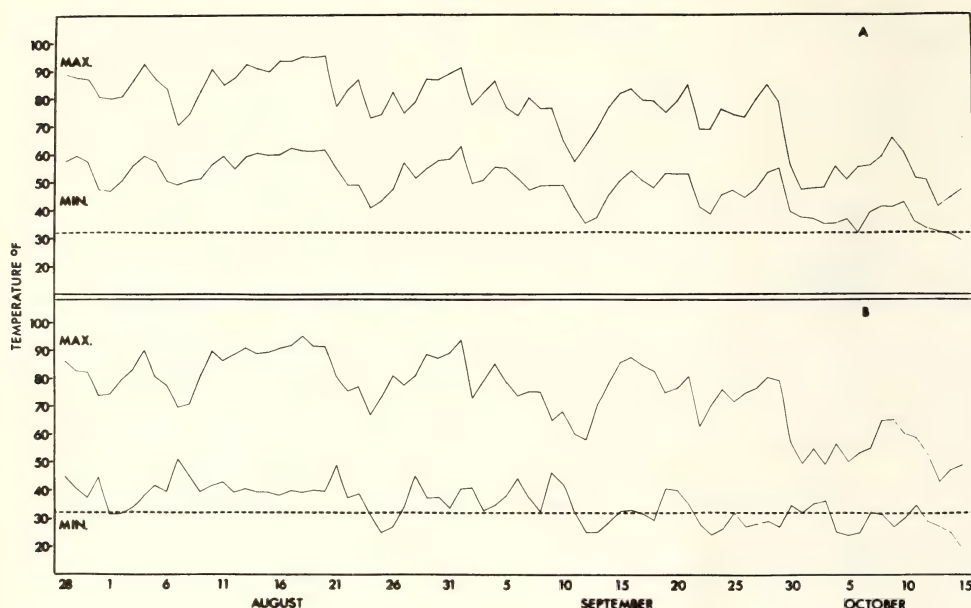


Fig. 2. Maximum and minimum daily temperatures from 28 July to 15 October 1967, at site A, on a mountain slope and at B, in a valley bottom.

Conclusions

Accumulated degree-hours above the development threshold and the date and severity of the first late-summer frost are important factors that affect the seasonal rate of *D. obesus* brood development. A very slight increase in accumulated heat during the season can make the difference between mature and immature broods.

In summer the valley bottoms are frequently as warm during the day as the higher areas on adjacent slopes. At night, they are often colder. The night temperature inversion creates a zone on the slopes with more degree-hours of heat and higher minimum

temperatures than in the valleys, particularly during late summer. Within this higher zone a larger percentage of *D. obesus* broods can mature in one season.

When the location of abundant breeding material, such as windfall, coincides with zones of rapid beetle development, the population of mature beetles greatly increases in one season. These beetles, combined with beetles maturing after 2 years in cooler sites, result in greater populations flying and attacking new hosts the following spring. The sudden increase in the pressure for suitable breeding sites may result in the invasion and death of standing timber.

TABLE 1

Percentage of larvae, pupae, and young adults in spruce logs on a mountain slope (site A) and in two valley bottoms (sites B and C) in 1967.

Site	23-24 August			18 October		
	Larvae ¹	Pupae	Adults	Larvae ¹	Pupae	Adults
A	38.6	38.6	22.8	4.0	0.0	96.0
B	8±.7	13.8	1.5	86.6	0.0	13.4
C	-	-	-	89.7	1.0	9.3

¹Larvae in last instar.

Acknowledgment

I thank L. H. McMullen and M. D. Atkins for critically reviewing the manuscript and D. W. Taylor and W. Kusy for assis-

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SOME OBSERVATIONS ON FLIGHT IN *ONCOPELTUS FASCIATUS* (HEMIPTERA: LYGAEIDAE)¹

R. J. HEWSON

ABSTRACT

Oncopeltus fasciatus (Dallas) is a typical Hemipteran with fore-wings modified to form hemielytra and membranous hind-wings. During flight, these two pairs of wings are linked together by a wing coupling apparatus. Observations were made on normal insects and insects with either fore- or hind-wings removed. The experiments demonstrated that the mesothorax with the fore-wings is the most important segment of the pterothorax in this insect. It was shown that the fore-wings provide the main propulsive force for flight and also provide much of the lift: the hind-wings provide extra surface for lift, but this is effective only if the wings are coupled together. As in the Lepidoptera and Hymenoptera, where the two pairs of wings are also linked together by a wing coupling apparatus, it appears that the musculature of the mesothorax may be the "driving force" for both pairs of wings.

Introduction

The Hemiptera (Heteroptera) possess two pairs of dissimilar wings; the fore-wings or hemielytra are modified and partially sclerotized, the hind-wings are thin and membranous. The two pairs of wings are normally hooked together during flight by a coupling apparatus (Weber, 1930). Comparing the Heteroptera with the Coleoptera, it might seem that the hemielytra would play little part in flight, most of the propulsion being provided

by the hind-wings. However, comparison with the Lepidoptera suggests that the fore-wings might be the more important, with the hind-wings of the Heteroptera receiving their power through the wing-coupling mechanism. The studies of Scudder (1967) on flight muscle polymorphism in Notonectidae show that the mesothoracic flight muscles may be reduced in flightless members of this group, with little or no change in the metathoracic musculature. Scudder therefore suggested that the mesothoracic segment with its hemielytra is the

¹ Part of a thesis for the M.Sc. degree in the Department of Zoology, University of British Columbia, Vancouver 8, Canada.

more important segment in the flight of the Heteroptera. In the present study, experiments were carried out to test the functions and the relative importance of the two pairs of wings in the Heteroptera.

Materials and Methods

Milkweed bugs, *Oncopeltus fasciatus* (Dallas), were chosen for study because they are typical terrestrial bugs, and are easy to rear. They were fed on milkweed seeds and kept between 73°F in the dark and 78°F in the light (av. 76°F), at absolute humidity of 28%, with a photoperiod of 14 hours light and 10 dark. Under these conditions, the adults lived about two months.

Experiments were carried out to determine the relative importance of the thoracic segment in flight. Tests were made to determine the age when the adult is first able to fly, and the best age for further trials. Speed and duration tests were performed on intact insects of known age on a flight mill having a circumference of 69.10 cm. To compare the separate contributions to flight of the mesothoracic and metathoracic wings, experiments were performed in which the wings were cut off at the base and the ability to fly, and the speed and duration of free flight were tested. Only specimens which had previously flown were used in wing removal experiments. Some observations were made using a Xenon stroboscope.

Flight was initiated in untethered adults by a toss into the air, and in tethered insects, by blowing from the anterior and simultaneously removing tarsal contact (Pringle, 1957). Untethered adults were considered to exhibit true flight when they flapped their wings and moved in a more or less horizontal direction from take-off; flight in a diagonally downward direction was also considered to be

true flight but a vertical drop was not, even if the wings were flapping. For tethered adults flight was judged to occur on forward motion of the mill.

Results

Flight Period

Tests showed that the adults would not fly until three days after the last moult (Table 1).

TABLE 1. Initiation of flight in 10 *O. fasciatus* at 5 age levels.

Age in days	No. flying	Action observed
General	0	none
1	0	wings extended
2	1	fluttering
3	5	flapping
4	6	flapping

It was concluded that insects used in succeeding experiments could not be less than three days old. The number of insects flying never exceeded 60% of the number tested, regardless of age. It could not be determined why apparently healthy adults resisted all efforts to initiate flight. Dingle (1965) found that eight-day-old *Oncopeltus* flew faster and longer than adults of any other age. This was confirmed in these experiments, and consequently, eight-day-old adults were used for succeeding experiments.

Normal flying insects, once flown on the flight mill, were reluctant to fly again on the mill. The reason is unknown, but was apparently not due to exhaustion. Previously tethered fliers would fly again untethered, and insects often showed mating behaviour minutes after being removed from the flight mill. Flight periods were usually from 2 to 30 minutes and rest periods between attempts ranged from 10 minutes to 24 hours.

Removal of Wings

Since not all adult insects would fly, it was necessary to test each insect untethered for a positive flight response before removing the wings. The experiments showed that the insects could fly with only the fore-

wings present, but were unable to fly with the hind-wings alone. When the fore-wings were removed the hind-wings were extended but no flapping occurred. There was no difference observed in the results between males and females (Table 2).

TABLE 2. Flight response after wing removal in 8-day-old *O. fasciatus*

	Males		Females	
	No. oper'd on	No. flying	No. oper'd on	No. flying
fore-wings removed	8	0	12	0
hind-wings removed	20	16	20	17

The observation that *Oncopeltus* can fly lacking hind-wings raised the question of the necessity of these wings.

Flight duration and speed could be measured accurately only on a flight mill, and since the insects refused to fly a second time on this instrument, good values, especially for insects

lacking hind-wings were difficult to obtain. Speed was measured on the flight mill in 10-sec intervals for the first 2 minutes and in 30-sec intervals after 2 minutes. It was impossible to obtain instantaneous readings for speed without sophisticated equipment, so the recorded speeds were averaged over the 10-sec or 30-sec intervals.

Both normal males and females showed an initial burst of speed, then slowed to a steady speed after 2 minutes for males and 3 minutes for females. Over the first minute, the average speeds were 63 ± 3 cm/sec for males and 54 ± 3 cm/sec for females. The steady speed was 57 ± 2.5 cm/sec for males, and 42 ± 5 cm/sec for females (Fig. 1).

From Fig 1, it appears that the best time to test flight speed is after the initial burst, while the steady speed is being maintained. This is possible for normal insects, which are

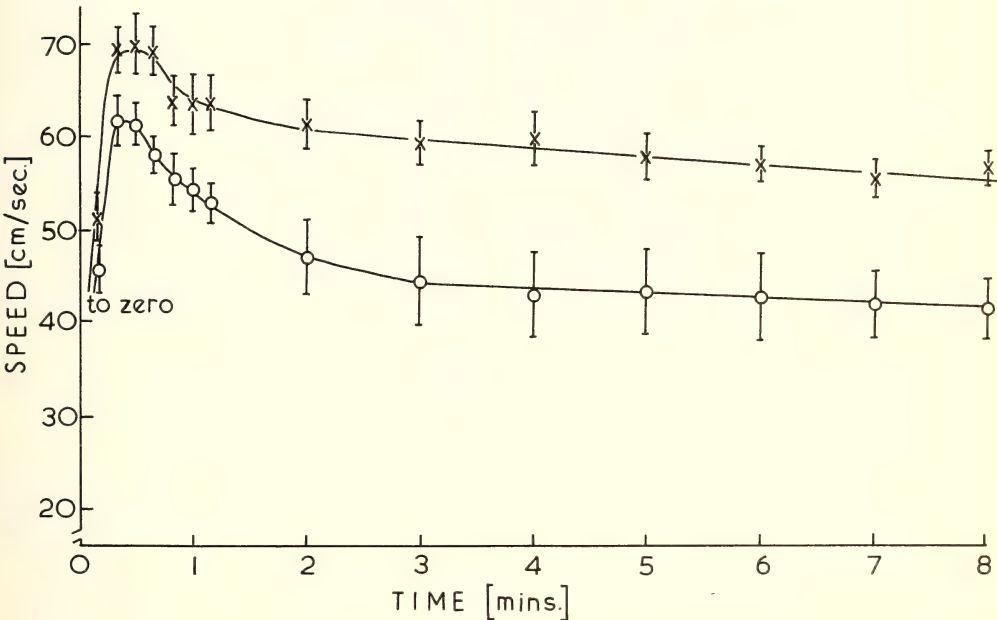


Fig. 1. Graph showing flight speed of 8-day-old *Oncopeltus fasciatus* on a flight mill: x = normal males (n = 10), o = normal females (n = 16) [mean \pm standard error shown for each point].

able to fly for several hours if necessary (Dingle, 1965). However, the longest duration recorded on the flight mill for insects lacking hind-wings was 9 sec. Several operated insects flew in 2- to 5-sec bursts, but no sustained flight was recorded (Table 3).

TABLE 3. Duration of flight on the flight mill after removing the hind-wings in 10 male and 10 female *O. fasciatus*, 8 days old

	No. flying	Duration in sec.	
		Av. (range)	
male	0	-	
female	4	3	(1-9)

The average speed for the few insects which flew on the flight mill following the removal of the hind-wings was computed to be 18 to 20 cm/sec, a value well below those for the normal insect (Fig. 1).

Lift was difficult to measure accurately, and so a subjective judgement was used. Four index values were assigned: 3 for insects flying diagonally upward, with lift greater than the insect's weight; 2 for insects flying directly horizontally, with lift equal to the insect's weight; 1 for insects flying diagonally downwards, with lift less than the insect's weight; and 0 for a vertical drop, with no lift present. With such numerical values, the lift could be averaged over a number of insects. The lift value was assigned after watching the insect take off and fly from the finger 2 or 3 times.

All normal insects showed lift equal to or greater than the insect's weight; those lacking hind-wings had significantly lower lift values, averaging less than the insect's weight; those lacking fore-wings showed no

lift at all. Only with both pairs of wings could adequate lift be maintained (Table 4).

Wing Coupling

Experiments were performed on insects with the wing-coupling apparatus removed from the fore-wings. The results were similar to those with the insects lacking hind-wings; lift and flight speed were reduced.

In order to determine whether or not the hind-wings were moving, the insects were observed while flying illuminated solely by a stroboscope, adjusted so that the actual wing movements could be seen. Most of the insects with the wing-coupling apparatus removed refused to fly long enough for adequate observations. However, in one intact insect, flying in front of the stroboscope, the wing-coupling mechanism became disengaged about 5 minutes after flying began. After several unsuccessful attempts to reconnect the wings, the insect continued to fly, using only the fore-wings. The hind-wings did not flap on their own, but were merely held, vibrating, at an upward angle. After several minutes in this position, the hind-wings folded over the back of the insect, assuming the resting position. The fore-wings continued to flap on their own for a further 10 minutes. It is not known whether the speed was reduced during flight with the wings uncoupled, because this insect was held on a stationery tether and not on the flight mill.

Discussion

Flight requires propulsion, lift, and stability. Propulsion and lift are functions mainly of the wings and their

TABLE 4. Index values of lift for normal and operated 8-day-old *O. fasciatus*

	Normal		Lacking hind-wings	
	Number tested	Average value	Number tested	Average value
male	47	2.1	14	1.3
female	46	2.4	12	1.2

musculature; stability is a function of the shape of the wings and the body.

The experiments described show that with the hind-wings removed, *O. fasciatus* can still provide the propulsion for flight; with the fore-wings removed, propulsion is not possible. It would seem therefore that for propulsion, the mesothorax and fore-wings are more important than the metathorax and hind-wings.

It is clear that the hind-wings are necessary for adequate flight and that they provide much of the lift. Insects lacking hind-wings were unable to maintain horizontal flight and would probably not be able to take off from the ground, since the lift force provided by the fore-wings alone is less than the weight of the insect. The hind-wings are therefore important in providing the extra surface necessary to increase the lift to a value greater than that of the insect's weight. For this extra surface area to be effective, the two pairs of wings must be coupled together to present a single surface area.

It was observed, in the insect whose coupling mechanism failed, that the hind-wings did not flap unless they were coupled to the fore-wings. One is therefore led to believe that the power for movement must come from the mesothorax, trans-

mitted to the hind wings through the fore-wings and the coupling mechanism. The hind-wings were observed to vibrate when uncoupled, indicating that the metathoracic musculature is capable of bringing about hind-wing movement. In the intact flying insect, however, the actual operation of the wings is evidently controlled from the mesothorax.

A similar situation is seen in the Lepidoptera and the Hymenoptera in which the two pairs of wings are also joined by coupling mechanisms, and the power for flight comes from the mesothorax. For adequate lift and propulsion, both pairs of wings are necessary, but both are controlled by the mesothoracic musculature, acting through the hook mechanism and through the metathoracic muscles in some cases (Chadwick, 1953; Pringle, 1968).

In the Heteroptera it would thus seem that the mesothoracic segment is the most important part of the pterothorax for flight. The modification of the fore-wings to form hemelytra has not progressed so far that it has reduced the functional significance of the mesothorax to the stage seen in the Coleoptera.

Acknowledgments

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PARASITES OF THE LARCH CASEBEARER, *COLEOPHORA LARICELLA* (HBN.), IN BRITISH COLUMBIA (LEPIDOPTERA: COLEOPHORIDAE)

R. J. ANDREWS and N. J. GEISTLINGER¹

ABSTRACT

The following nine species of parasites and hyperparasites were recovered from rearings of the larch casebearer, *Coleophora laricella* (Hbn.), in Interior British Columbia, 1966-1968: *Bracon* sp., *Scambus decorus* Wly., *Scambus transgressus* (Holmg.), *Gelis tenellus* (Say), *Dicladocerus westwoodii* (Westw.), *Tetrastichus xanthops* (Ratz.), *Amblymerus* prob. new sp., *Sceptrothelys deione* (Wlk.) and *Spilochalcis albifrons* Walsh.

The larch casebearer, *Coleophora laricella* (Huebner), was introduced from Europe to the eastern United States in the 1880's and spread to the Lake States and Ontario and Quebec. The insect was found infesting western larch near St. Maries, Idaho, in 1957, and subsequently spread into northeastern Washington and northwestern Montana. It was first discovered in British Columbia in 1966 near Rossland and in the valleys of the Yahk and Salmo rivers. It has spread as far north as Lardeau at the north end of Kootenay Lake, west to Anarchist Mountain near Osoyoos and east to the Kootenay River. Populations in British Columbia have increased rapidly and caused light damage. Repeated defoliation by the casebearer causes significant reduction in terminal and radial growth and occasionally kills branchlets, and may kill trees.

Over 50 species of native parasites have been reared from larch casebearer in eastern Canada and the United States, but none in significant numbers. Two introduced parasites, *Agathis pumila* (Ratzburg) and *Chrysocaris laricinellae* (Ratzburg), have become well established in eastern infestations. Releases of *A. pumila* in Idaho in 1960 resulted in the success-

ful establishment of this parasite in Western larch infestations in the United States, but it has not been released or recovered in British Columbia, although releases are planned.

The parasites associated with the larch casebearer in British Columbia were investigated in 1966, 1967 and 1968 to determine their significance, and to find out if *A. pumila* had spread into the Province from the United States. Casebearer larvae were collected from several localities each year between 16 May and 14 June and reared on larch branches in cloth-covered cages at the Forest Entomology Laboratory in Vernon. In all, nine species of hymenopterous parasites and hyperparasites have been recovered from these rearings. Following is a list of those reared at Vernon and identified by Dr. W. R. M. Mason, Dr. O. Peck and Mr. G. S. Walley of the Systematics Unit, Entomology Research Institute, Ottawa.

BRACONIDAE

Bracon sp. - 1 specimen from Osoyoos, B.C. emerged 18-VI-68.

ICHNEUMONIDAE

Scambus decorus Walley - 2 specimens from Creston, B.C. emerged 5-VI-67 and 6-VI-67.

Scambus transgressus (Holmgren) - 13 specimens from Creston, B.C. emerged 10-VI-68 and 12-VI-68.

Gelis tenellus (Say) - 1 specimen from Salmo, B.C. emerged 27-VI-68; 1 specimen from Creston, B.C. emerged 18-VI-68.

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EULOPHIDAE

Dicladorcerus westwoodii (Westwood) - 6 specimens from Creston, B.C. emerged 18-VI-68.

Tetrastichus xanthops (Ratzburg) - 2 specimens from Creston, B.C. emerged 18-VI-68.

PTEROMALIDAE

Amblymerus probably new sp. - 4 specimens from Salmo, B.C. emerged 18-VI-68; 6 specimens from Creston, B.C. emerged 14-VI-68 and 18-VI-68.

Sceptrothelys deione (Walker) - 2 specimens from Creston, B.C. emerged 14-VI-68.

CHALCIDIDAE

Spilochalcis albifrons Walsh - 12 specimens from Creston, B.C. emerged 27-VI-68; 7 specimens from Salmo, B.C. emerged 27-VI-68; 5 specimens from Salmo,

B.C. emerged 5-VII-66, 6-VII-66, 7-VII-66, 18-VII-66.

All parasites were recovered from ultimate instar larvae or pupae of *C. laricella*.

G. tenellus is a common hyperparasite and *S. albifrons* is often hyperparasitic.

In 1966, 0.69% of 1,004 casebearers reared at Vernon were parasitized; in 1967, 0.22% of 881 casebearers were parasitized and in 1968, 4% of 1,360 casebearers reared were parasitized, with the greatest percentage (14% of 208) occurring near Creston.

LABORATORY REARING OF *NOTONECTA UNDULATA* SAY (HEMIPTERA : NOTONECTIDAE)

R. A. ELLIS AND J. H. BORDEN¹

ABSTRACT

Four generations of *Notonecta undulata* Say were reared in the laboratory within a year. Adults were kept in 15 gallon oviposition aquaria maintained at a temperature of $25 \pm 1^\circ\text{C}$ and a pH of 6.5 - 7.5. Eggs were transferred to an incubation aquarium kept under identical conditions. Nymphs were reared individually in 100 ml glass beakers. Live prey were supplied regularly for food.

Notonecta undulata Say, one of the most common species of backswimmer in North America, is a predaceous water bug found in many fresh - water habitats throughout Canada and the United States. Various aspects of its life-history, ecology and behavior are known (Bueno 1905; Essenburg 1915; Hungerford 1917, 1919; Clark 1928; Clark and Hersh 1939; Ellis and Borden 1969). Adults can be collected throughout the year in southwestern British Columbia, although with considerable difficulty during the winter. Because *N. undulata* is suitable for biological studies, we have, therefore, developed a technique by which this species may be reared in the laboratory.

In southwestern British Columbia there are generally two generations per year. Our colony was started in April, 1967, from field-collected adults and has continued for 23 months.

The rearing conditions were as follows: backswimmers were kept in covered 15-gallon aquaria, filled with tap water that had been aerated for at least 24 hours to remove chlorine. Aquaria were equipped with a filter-aerator, pH was 6.5-7.5 and temperature was maintained at $25 \pm 1^\circ\text{C}$ by a standard aquarium heater. The backswimmers were kept under natural daylight. The aquaria were covered with canopies to prevent the escape of adults, two 25-watt light bulbs being used to facilitate periodic inspection. The bottoms of the aquaria were covered with sand, and several pieces of green rubber-mesh

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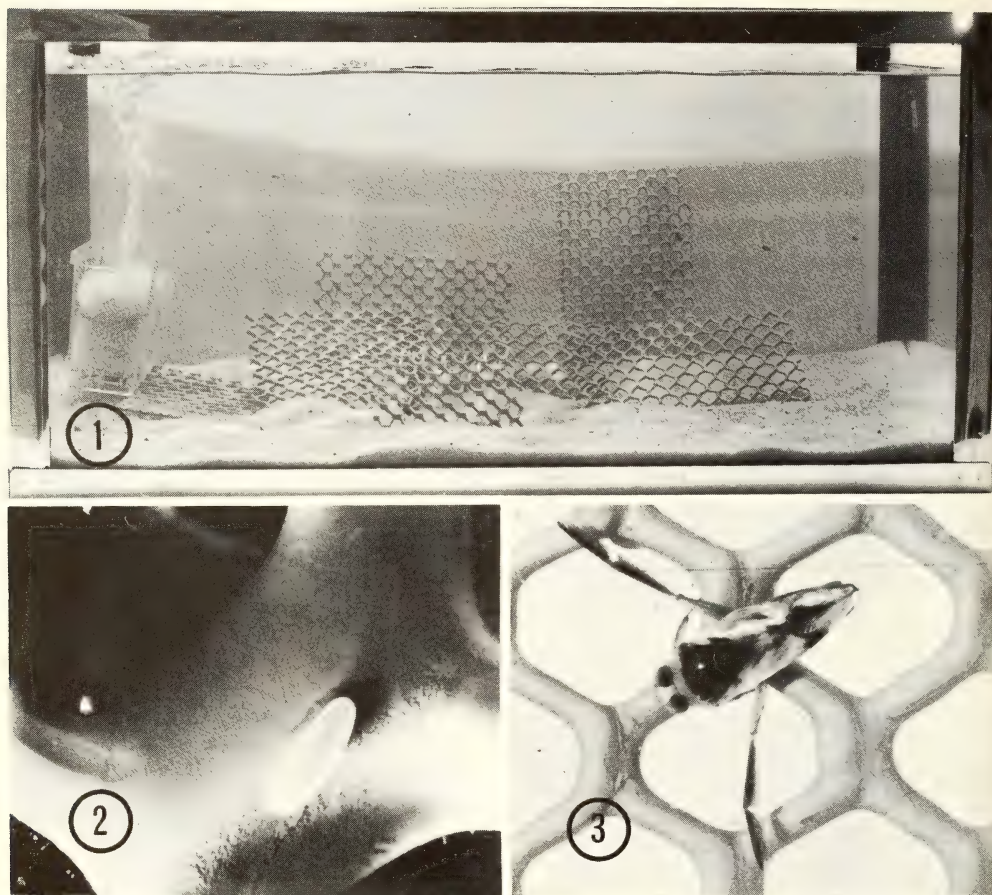


Fig. 1. Oviposition aquarium for *N. undulata*.

Fig. 2. Newly laid egg on rubber-mesh sink matting

Fig. 3. Adult backswimmer using mesh for anchorage.

were provided for cover, anchorage and oviposition (Figs. 1, 2 and 3). Food supplied daily, consisted of small- to medium-sized insects dropped onto the surface. When daily feeding was not possible other aquatic insects, such as mosquito and midge larvae, left in the aquaria, provided a convenient source of food. Under these conditions, up to 15 adults were kept in an aquarium without significant cannibalism and eggs were obtained.

Plants, such as *Anacharis canadensis* Michx. (McPherson 1966, Ellis and Borden 1969), or even sodden

leaves (Clark and Hersh 1939) can be used with some success, but due to water temperature and necessary handling they soon deteriorate. This may occur before all the eggs have hatched. The sink matting, however, lasts indefinitely.

Matting on which eggs were laid was transferred to aquaria away from the adults. At 25°C the eggs hatched in 1-2 weeks. On hatching, first instar nymphs were placed individually in 100 ml glass beakers half filled with water and kept at 25°C. Nymphs were fed on a similar diet to that of the adults.

Under these conditions we have produced seven generations in 23 months.

Acknowledgments

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HYMENOPTEROUS PARASITES OF THE HEMLOCK SAWFLY, *NEODIPRION TSUGAE* MIDDLETON, IN SOUTHEAST ALASKA, WITH A KEY TO LARVAL REMAINS

TOROLF R. TORGERSEN¹

ABSTRACT

A key is supplied to identify parasitic Hymenoptera reared from hemlock sawfly cocoons in southeast Alaska. The key is based on the size of the exit hole in the host cocoon, and characters visible on the final-instar larval skin. Brief biological and descriptive notes are given for each species appearing in the key.

Introduction

The hemlock sawfly, *Neodiprion tsugae* Middleton, is an important defoliator of western hemlock, *Tsuga heterophylla* (Raf.) Sarg., in south-east Alaska. Heavy defoliation occurred during the early 1950's (Downing, 1957) and 1960's (Crosby, 1965). Usually epidemics are severe for only a year or two, but noticeable defoliation may continue for several years. Although outbreaks may subside with little immediate effect, top-killing and whole-tree mortality sometimes occur. This is especially true when the

sawfly is found in association with or following infestations of the black-headed budworm, *Acleris variana* (Fernald) (Downing, 1959).

The parasite species reared from hemlock sawfly cocoons in Alaska were listed by Torgersen (1968). The paper includes a key to the parasite adults and notes on the abundance of each species. No dipterous parasites have been reared from the sawfly.

The following key, based on the appearance of mature larval remains and host cocoon, includes all but three of the parasite species reared from the sawfly in Alaska to date. The species were omitted because final-instar larval remains were not

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available for study. The parasites included in the following key are: *Amblymerus verditer* (Norton) (Pteromalidae); and *Itopectis quadricingulatus* (Provancher), *Delomerista japonica diprionis* Cushman, *Rhorus* sp., *Lamachus* spp., *Mastrus* spp., and *Opidnus tsugae tsugae* (Cushman) (Ichneumonidae).

**KEY TO PARASITES OF THE
HEMLOCK SAWFLY
BASED ON COCOON AND FINAL-
INSTAR LARVAL REMAINS**

1. Parasite exit hole in host cocoon less than 0.92 mm in diameter; final-instar cephalic structure apparently limited to mandibles (Fig. 1) ***Amblymerus verditer***
Parasite exit hole greater than 0.94 mm in diameter; final-instar cephalic structure complete or nearly so (Figs. 2-7) **2**
- 2(1). Final-instar cephalic structure with epistoma, pleurostomae, hypostomal spurs, and venter of labial sclerite approximating a ring; hypostomae absent (Fig. 7); spiracles as in Fig. 13 ***Itopectis quadricingulatus***
Final-instar cephalic structure not as above; hypostomae present (Figs. 2-6) **3**
- 3(2). Vertex of final-instar head capsule with four heavily sclerotized areas; blade of mandible with a large tooth basally (Fig. 3); atrium of spiracle funnel-shaped (Fig. 10) ***Delomerista japonica diprionis***
Vertex of final-instar head capsule without noticeable heavily sclerotized areas; blade of mandible without a large tooth basally (Figs. 2, 4-6); atrium not as above **4**
- 4(3). Blades of mandibles very short (Fig. 4) ***Rhorus* sp.**
Blades of mandibles well developed (Figs. 2, 5, 6) **5**
- 5(4). Labial sclerite incomplete ventrally; medial face of dorsal arms expanded and serrated; antennal socket only present (Fig. 5) ***Lamachus* spp.**
Labial sclerite complete ventrally; dorsal arms not markedly expanded or serrated; antennae present (Figs. 2, 6) **6**
- 6(5). Stalk of spiracle longer than diameter of atrium (Fig. 9); cephalic structures as in Fig. 2 ***Mastrus* spp.**
Stalk of spiracle shorter than diameter of atrium (Fig. 12); cephalic structures as in Fig. 6 ***Opidnus tsugae tsugae***

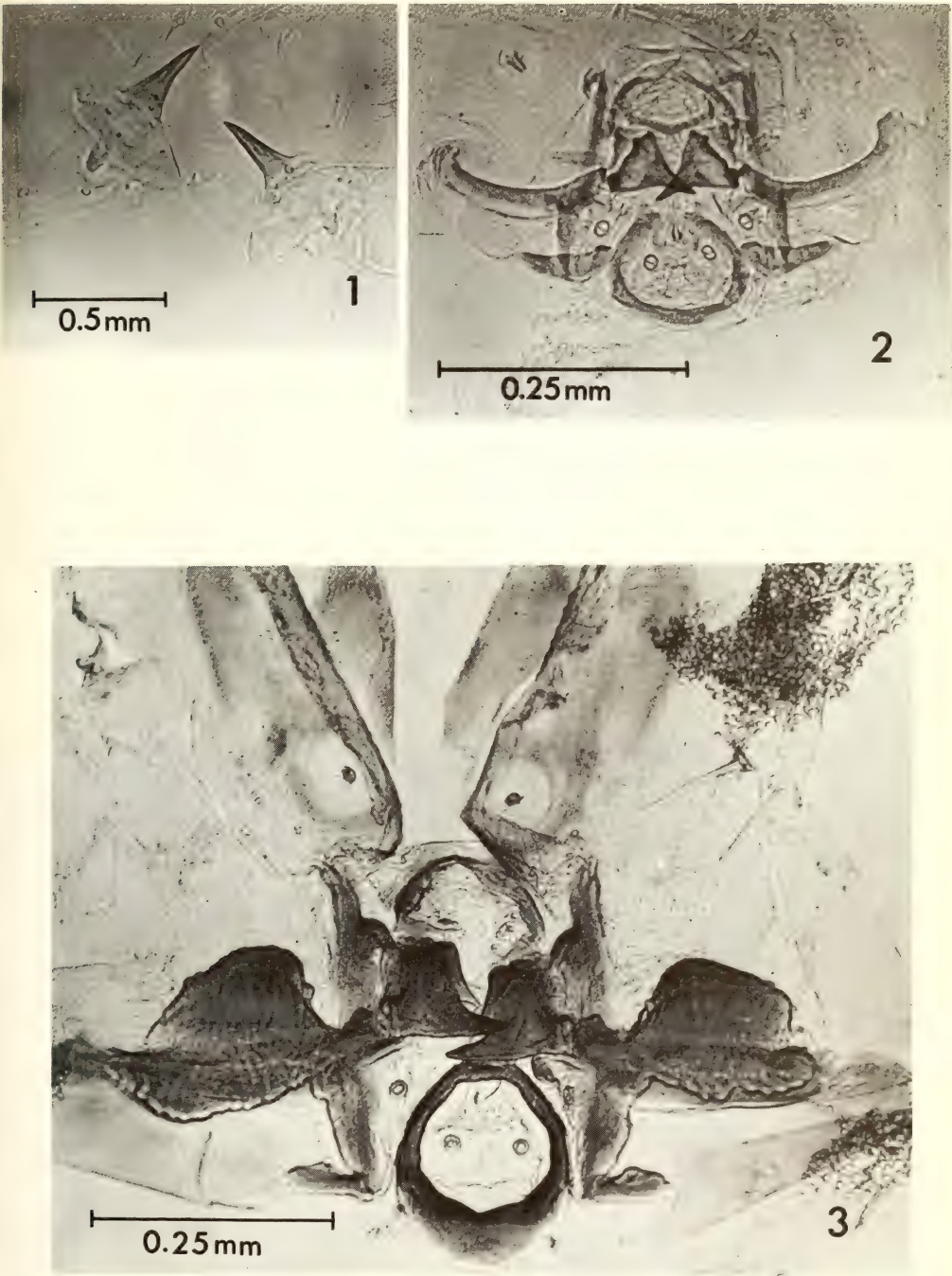
Methods

Collections of sawfly eggs, larvae, and cocoons were made at several locations in southeast Alaska from 1964 through 1967. Branches with sawfly eggs were collected in May, and larval collections were made at intervals during the larval development period from about mid-June to mid-August. Cocoons were collected throughout the year to obtain all life stages of parasites.

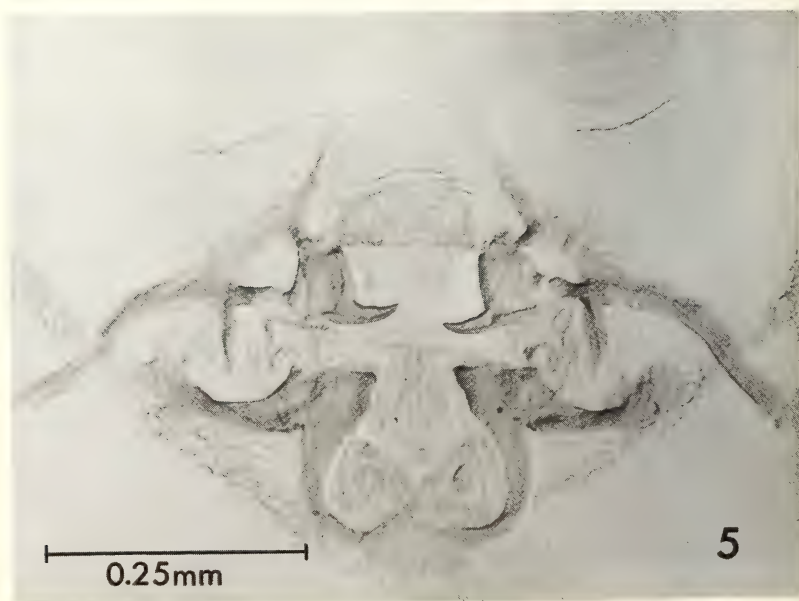
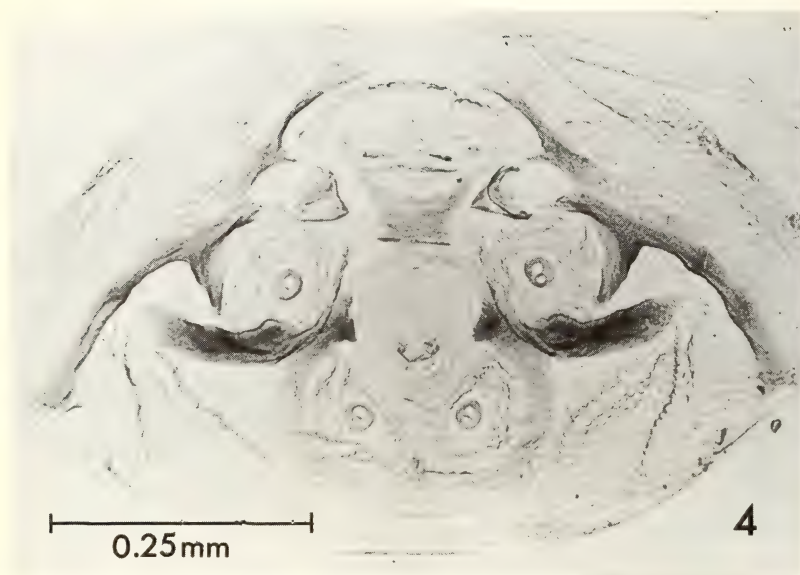
In the laboratory, egg-bearing branches were placed in plastic rearing cages at room temperature. Larvae were placed in rearing cages containing fresh hemlock foliage which was replaced as needed. Cages were examined daily and dead or moribund larvae removed along with newly formed cocoons. Mortality was recorded, and moribund larvae and the cocoons were placed in individually coded gelatine capsules. Capsules were kept in controlled temperature cabinets at 16 or 21°C. Field-collected cocoons also were put in capsules and placed in cabinets. Fall-collected cocoons were kept at 7°C for 30 to 60 days before transferring them to the warmer cabinets. Emerging parasites were removed daily, identified, and the emergence data recorded by species. Parasites were kept with the cocoons from which they emerged.

Information on host and parasite remains was obtained from dissections of cocoons from which known species of parasites emerged. Data such as size and shape of exit hole, color and shape of parasite cocoon, disposition of meconium and parasite larval and host remains, and other pertinent observations were noted.

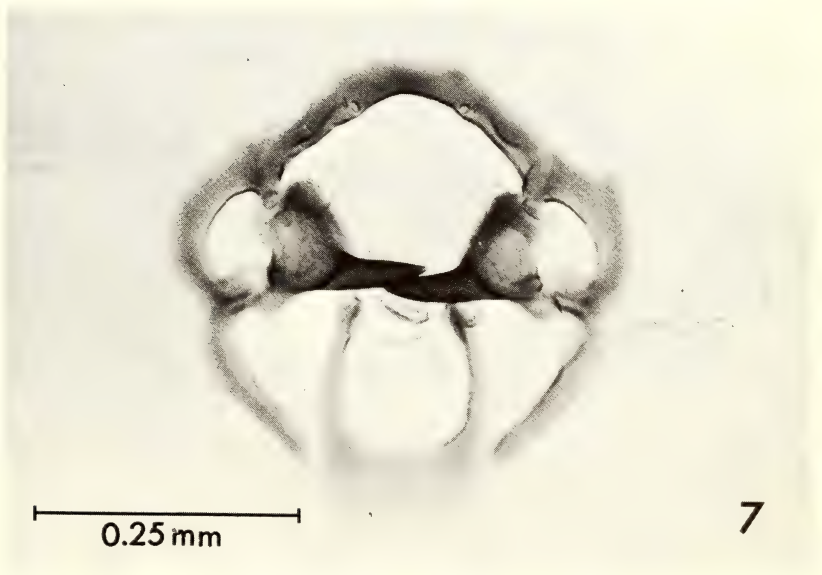
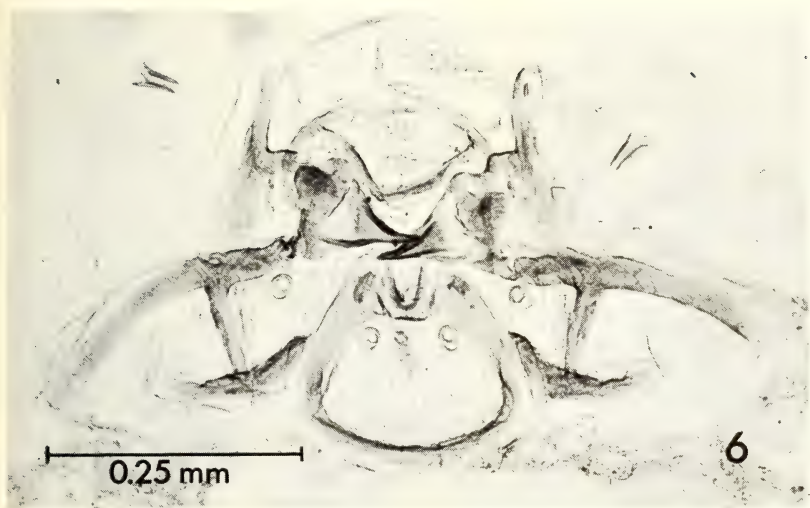
Mature parasite larval remains were mounted on microscope slides for study. Parasite larval skins were first thoroughly wetted by dipping in 95% ethanol, then soaked in a 10% potassium hydroxide solution for 15



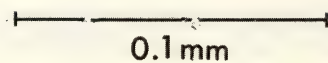
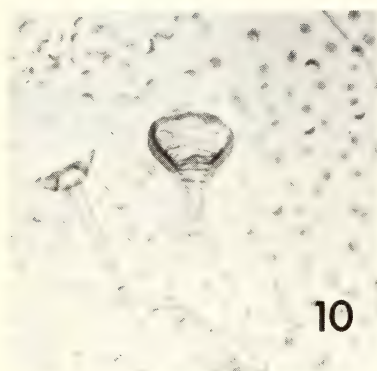
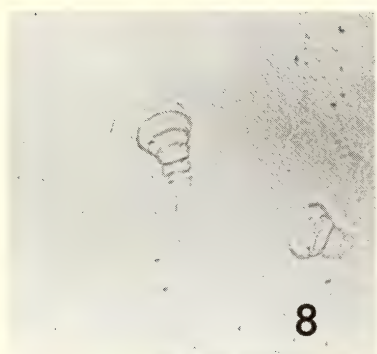
Figs. 1-3. Final-instar cephalic structures: 1, *Amblymerus verditer* (Norton); 2, *Mastrus* sp.; 3, *Delomerista japonica diprionis* Cushman



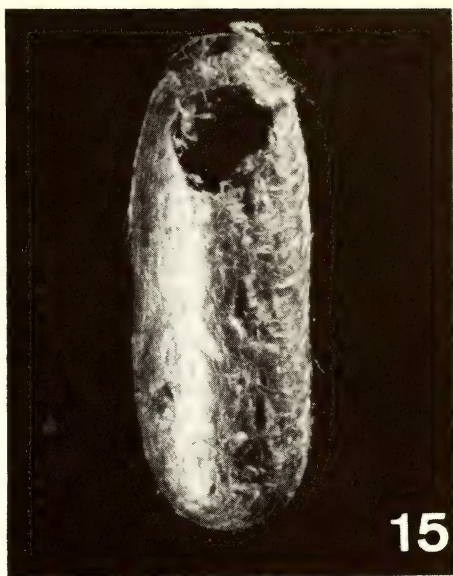
Figs. 4-5. Final-instar cephalic structures: 4, **Rhorus** sp.; 5, **Lamachus** sp.



Figs. 6-7. Final-instar cephalic structures: 6, *Opidnus tsugae tsugae* (Cushman); 7, *Itoplectis quadricingulatus* (Provancher).



Figs. 8-13. Spiracles of final-instar larvae: 8, *Amblymerus verditer* (Norton); 9, *Mastrus* sp.; 10, *Delomerista japonica diprionis* Cushman; 11, *Lamachus* sp.; 12, *Opidnus tsugae* (Cushman); 13, *Itoplectis quadricingulatus* (Provancher).



Figs. 14-15. Parasite exit holes in cocoons of *Neodiprion tsugae* Middleton: 14, exit hole of *Amblymerus verditer* (Norton); 15, exit hole of *Opidnus tsugae tsugae* (Cushman).

to 30 minutes, or until the skin was soft enough to manipulate. No staining was done; the softened skin was washed in water and mounted on a microscope slide in a nonresinous mounting medium (Turtox CMC-10). Photographs of the cephalic structures and spiracles were taken using a trinocular compound microscope fitted with a 35mm camera.

Biological and Descriptive Notes

Amblymerus verditer (Norton)

A. verditer (Figs. 1, 8, and 14) usually occurred as a secondary parasite of the sawfly. This species was a primary parasite in 10 cases out of 94 studied. The primary parasites on which *A. verditer* developed were *Opidnus tsugae tsugae*, *Itoplectis quadricingulatus*, and *Lamachus* spp. Furniss and Dowden (1941) listed *A. verditer* as a parasite whose role as a primary or secondary was uncertain.

Laboratory emergence of *A. verditer* occurred from mid-August

through early September, from cocoons collected in the field from early May through mid-August. This species was usually a solitary parasite, but multiple emergences of up to 11 individuals from the same cocoon were recorded.

A single exit hole (Fig. 14), rarely two, is cut in the sawfly cocoon even when multiple emergence is involved. The nearly round hole is ca. 0.8 mm (0.7-0.9 mm) in diameter; subapical, sometimes apical or on the side. No parasite cocoon is constructed. The white final-instar larval skin is usually closely associated with the fractured, honey-colored pupal skin. *A. verditer* remains are found in the sawfly cocoon with the primary parasite larval or pupal remains.

Final-instar cephalic structure with only mandibles clearly visible (Fig. 1); antennae prominent. The final-instar larval remains of *A. verditer* were described and illustrated by Finlayson (1960b).

Itoplectis quadricingulatus
(Provancher)

I. quadricingulatus (Figs. 7, 13) oviposits on sawfly larvae in cocoons; rarely, the host is a pupa. Cocoons collected in the field produced parasites by the first week in June, and adults were collected in the field by the third week in June. Field-collected cocoons obtained as late as mid-August produced parasites in the laboratory within 2 or 3 weeks. Considering the long period over which *I. quadricingulatus* emerges during the summer, it is possible that this species is multivoltine in Alaska. This possibility was suggested by Furniss and Dowden (1941) who collected this species in Oregon. *I. quadricingulatus* is also a parasite of the black-headed budworm, *Acleris variana*, in Alaska.

Exit hole roughly round, ca. 1.6 mm (1.1-2.2 mm) in diameter. Margin jagged, with slivers of cocoon attached to the edge or loose inside the cocoon. Parasite cocoon thin, semi-transparent, light brown or white; laid down inside of and closely appressed to host cocoon, or may be limited to a silken disc covering the host remains. Host remains are at end of cocoon opposite exit hole or adjacent to it. Final-instar larval remains loosely associated with meconium at end of cocoon opposite exit hole; sometimes absent.

Final-instar cephalic structure characterized by lack of hypostomal arms; general aspect suggests a sclerotized ring surrounding the mandibles (Fig. 7). Atrium of spiracle flattened above and below, with a scattering of projections on the inner wall. A short stalk leads to a well-developed closing apparatus (Fig. 13).

Delomerista japonica diprionis
Cushman

D. japonica diprionis (Figs. 3, 10) parasitizes the hemlock sawfly larva

within the cocoon. According to Furniss and Dowden (1941), this parasite is univoltine; the egg is laid externally on the larva and the winter is passed as a mature larva. In Alaska, adults in flight have been collected on 23 June, and the latest adult emergence from field-collected cocoons was early August.

Mean diameter of emergence hole is ca. 1.6 mm (1.0-2.2 mm). Exit hole round or oval; situated with at least its margin reaching the apex, sometimes subapical; margin jagged with crescent-shaped pieces of cocoon loosely attached. Host remains are near exit hole or at opposite end of cocoon. Parasite cocoon apparently absent, represented only by a dark brown silken cap walling off the host remains. Parasite remains consist of a dark final-instar exuvium and a lighter yellow or cream pupal skin, one or both of which may be missing.

Final-instar head capsule typified by having four heavily sclerotized areas on the vertex. Cephalic structures heavily sclerotized; hypostomae well developed; blade of mandible with a heavy tooth basally (Fig. 3). Atrium funnel-shaped, opening into a well-defined closing apparatus (Fig. 10). Skin with conspicuous setae. The final-instar cephalic structure and spiracles were described and illustrated by Finlayson (1960a).

Rhorus sp.

A single specimen of *Rhorus* (Fig. 4) was reared from a sawfly cocoon collected 30 July 1963.

Exit hole round with a jagged margin; 1.5 mm in diameter; subapical. Parasite cocoon thin, silky white, laid down on wall of host cocoon. Sawfly larval remains walled off outside of parasite cocoon. Parasite remains associated with the meconium at opposite end from exit hole.

Final-instar cephalic structure

characterized by mandibles with poorly developed blades, incomplete epistoma, and lightly sclerotized labial sclerite with dorsal arms bearing serrations medially (Fig. 4). Larval skin with pebbled surface; no spiracles were found.

Lamachus spp.

Lamachus spp. (Figs. 5, 11) reared from the hemlock sawfly were identified by taxonomists as *Lamachus* sp., or *Lamachus tsugae* or a new species near it. According to Furniss and Dowden (1941), *L. tsugae* Cushman and *L. oregon* Cushman (= *L. angularis* (Davis)) are parasites of *Neodiprion tsugae* in Oregon. Their studies indicated that *L. oregon* and *L. tsugae* parasitized late-instar larvae and emerged from the cocoon the following spring.

In Alaska, no sawflies collected as larvae yielded parasites in this genus. However, dissections of late-instar larvae revealed the presence of *Lamachus* larvae within them. Field-collected cocoons had parasites emerging from early June through early July. Cocoons containing sawfly larvae parasitized by *Lamachus* spp. were collected by late July.

Exit hole very jagged with some slivers hanging from the margin; ca. 1.6 mm in diameter (1.4-1.9 mm); margin reaching apex of cocoon. Host a larva; remains closely appressed to inside of its cocoon. A thin white parasite cocoon is laid down inside of host cocoon. Final-instar larval and pupal remains are associated with the meconium at opposite end of cocoon from exit hole. Final-instar cephalic structure with labial sclerite incomplete ventrally, and with expanded and serrated dorsal arms (Fig. 5). Atrium of spiracle small, little larger than stalk (Fig. 11).

Mastrus spp.

All specimens of *Mastrus* spp.

(Figs. 2, 9) collected were solitary parasites of larvae, and sometimes pupae. The earliest collection date for sawfly cocoons from which *Mastrus* emerged was 2 September. The specimens of *Mastrus* spp. collected in this study were classified by taxonomists as *Mastrus* sp., *Mastrus* sp. nr. *argeae* (Vier.), and *Mastrus* sp. ? n.

Exit hole regular or slightly irregular in outline; diameter ca. 1.2 mm (1.2-1.4 mm); margin reaching to apex or slightly below. Parasite cocoon the same size and shape as host cocoon; dark brown to buff; sometimes two-layered with inside layer lighter in color.

Final-instar cephalic structure (Fig. 2) resembles *Opidnus tsugae tsugae* (Fig. 6), but smaller; width of labial sclerite ca. 0.15 mm (0.14-0.17 mm). Stalk of spiracle longer than diameter of atrium (Fig. 9).

Opidnus tsugae tsugae (Cushman)

O. tsugae tsugae (Figs. 6, 12, and 15) is the most common parasite reared from sawfly cocoons in Alaska (Torgersen, 1968). The host within the cocoon is usually a larva, but in about 5 percent of the dissections, pupal host remains were found. Furniss and Dowden (1941) recorded this species under the name *Aptesis* (*Pezoporus*) *tsugae* Cush., as a parasite of the sawfly in Oregon. They indicated that it was apparently multivoltine and attacked cocoons containing the prepupa.

In Alaska, *O. tsugae tsugae* adults are in flight by early June. Laboratory emergence from cocoons collected during June was complete by the first week in July. The following year's brood are present in cocoons collected in mid-August.

Exit hole roughly round or larger in one dimension; mean diameter ca. 1.4 mm (1.1-1.9 mm). Margin of exit

hole jagged, usually with pieces of cocoon adhering to it (Fig. 15). Hole situated apically or subapically. Parasite cocoon thin, laid down as a layer on inside of host cocoon; host remains are walled off outside parasite cocoon. Parasite final-instar remains are closely associated with the meconium.

Final-instar cephalic structure (Fig. 6) similar to *Mastrus* spp. (Fig. 2), but larger; width of labial sclerite

in *O. tsugae tsugae* ca. 0.20 mm (0.17-0.22 mm). Stalk of spiracle shorter than diameter of atrium (Fig. 12).

Acknowledgments

The author gratefully acknowledges the assistance of Miss L. M. Walkley of the Insect Identification and Parasite Introduction Branch, Agricultural Research Service, U.S.D.A., Washington, D.C., for identifying many of the parasites collected in connection with this study; and (Mrs.) Christine Andrew for assisting with slide preparations and photomicrographic work.

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FINAL-INSTAR LARVAE OF TWO HYMENOPTEROUS PARASITES OF A WOOD-BORING BEETLE, *TETROPIUM VELUTINUM* LeCONTE (COLEOPTERA: CERAMBYCIDAE)

THELMA FINLAYSON¹

ABSTRACT

Characteristics of the cephalic structures, spiracles and skin of final-instar larvae of two hymenopterous parasites, *Helconidea occidentalis* (Cress.) and *Rhimphoctona atrocotalis* (Ashm.), whose cocoons were found in galleries of the wood-boring beetle, *Tetropium velutinum* LeConte, are described and illustrated.

The species of wood-infesting Coleoptera of economic importance to western larch, *Larix occidentalis* Nuttall in British Columbia were investigated by Dr. D. A. Ross, Forest Entomology Laboratory, Canada Department of Forestry, Vernon, B.C.

(Ross 1967 a, b). During the course of that investigation two species of parasites were reared, and subsequently a section of log from which they emerged was made available to the author for study. As specific information on wood-boring beetles and their parasites is scarce this log from which both beetles and parasites had

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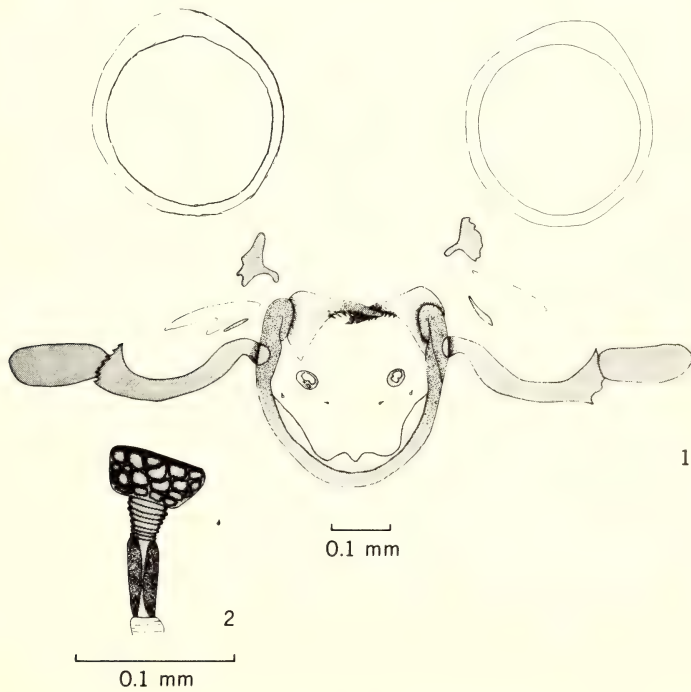
emerged provided an opportunity to establish positive host-parasite relationships.

The 2.5-foot section examined was part of a log felled on June 16th, 1965, at Houser Ridge, near Lardeau, north of Kootenay Lake, B.C. Adults of *Tetropium velutinum* LeConte (Coleoptera: Cerambycidae) emerged between May 9th and June 8th, 1966, and September 3rd, 1966, and of *Serropalpus* sp. (Coleoptera: Melandryidae) between June 29th and September 3rd, 1966, and between June 13th and 16th, 1967 (D. A. Ross, in litt.). The parasite species *Helconidea occidentalis* (Cress.) (Hymenoptera: Braconidae) emerged from May 29th to June 10th, 1966, and *Rhimphoctona atrocoxalis* (Ashm.) (Hymenoptera: Ichneumonidae) from May 19th to 30th, 1966 (D. A. Ross, in litt.).

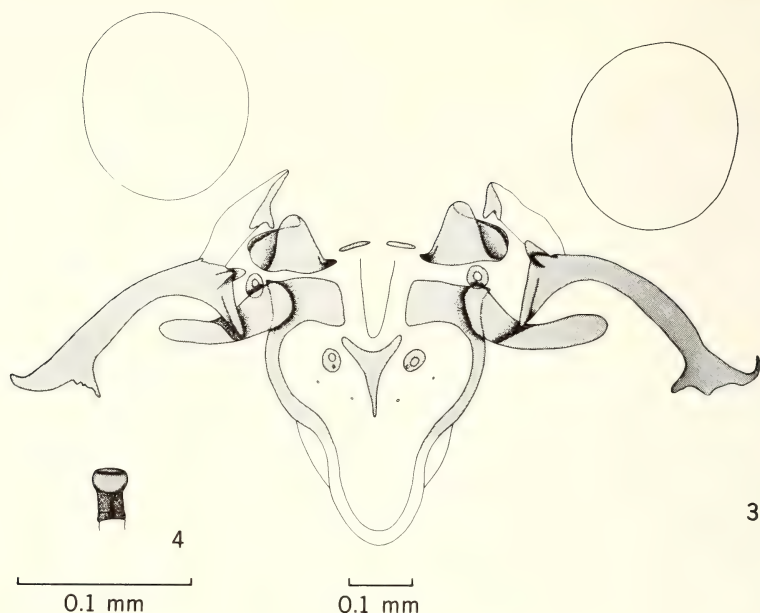
The log was cut into three-inch

sections, and each section was then quartered. The sections and quarters were labelled so that each beetle gallery could be followed throughout its entire course. Each section of log was chipped apart and 3-dimensional drawings were made so that the length and type of burrows could be determined. The larval entrance holes of *T. velutinum* are elliptical (Ross 1967 b) and the galleries examined in this work extended horizontally from one-eighth to one inch inward, then usually turned at almost a right-angle and extended vertically for three-quarters to one inch. *Serropalpus* sp. has round larval entrance holes (D. A. Ross, in litt.) and the galleries examined extended horizontally into the wood, curving gently, if at all, and extended for a distance of up to three inches, with occasional branching.

The cocoons from which parasites had emerged were found only at the



Figs. 1-2. Final-instar larva of *Helconidea occidentalis* (Cress.): 1, cephalic structure; 2, spiracle.



Figs. 3-4. Final-instar larva of *Rhimphoctona atroxalis* (Ashm.): 3, cephalic structure; 4, spiracle.

ends of the *Tetropium* galleries and in every case were filled with fine wood chips or wood powder. None was found in the *Serropalpus* galleries. The cocoons of both parasite species contained meconium and final-instar larval skins. The methods of preparing slides of the final-instar cast skins and the terminology used are similar to those described by Finlayson (1960).

Braconidae

Helconinae: Helconini

Helconidea occidentalis (Cress.)

(Figs. 1, 2)

The cocoon of this species is about 10 mm long by 3 mm wide, buff-coloured and fairly transparent, and thin, but mica-like in texture. The large exit hole on the end of the cocoon is ragged in outline.

Only one specimen was suitable for study of the cephalic structure and some of the relationships of the scler-

ites in this single preparation were difficult to determine. Cephalic structure of final-instar larva (Fig. 1) lacks epistoma; superior mandibular processes are present; inferior mandibular processes, pleurostoma and hypostoma are indistinct although showing traces; hypostomal spur entirely lacking. Stipital sclerite long and curved with bulbous appendage on lateral end; medial end touches labial sclerite on dorsal third. Labial sclerite U-shaped with dorsal part of lateral arms enlarged and slightly twisted. Mandibles with long, slightly-curved blade with what appears to be two rows of teeth. Maxillary palpi are not visible but the labial palpi are well defined, each with one large and two or three small sensoria. Antennal socket characterized by slightly sclerotized band with one sensorium. Spiracle (Fig. 2) has large atrium with more or less circular reticulations and opens into stalk with about

eight narrow annulations and strong closing apparatus. Skin densely covered with fine spines and occasional short setae. Of those final-instar cephalic structures of Braconidae illustrated in the literature, the cephalic structure of *Helconidea* most closely resembles those of the Cheloninae (see e.g. Finlayson 1967, Short 1952).

Ichneumonidae: Porizontinae

Rhimphoctona atrocoxalis (Ashm.)
(Figs. 3, 4)

Cocoon of *Rhimphoctona atrocoxalis* (Ashm.) about 10.5 mm long by 3.2 mm wide; light beige in colour; thin and weak but mica-like in texture. Remains of final-instar larva are in meconium at end of cocoon opposite exit hole. Exit hole is on tip of cocoon, jagged in outline, and about 3.2 mm in diameter.

Cephalic structure of final-instar larva (Fig. 3) with incomplete epistoma; superior mandibular process sclerotized, inferior mandibular process with two struts, the posterior one slightly longer than the anterior; pleurostoma unsclerotized. Hypostoma long and strongly curved ven-

trally. Heavy-based hypostomal spur meets stipital sclerite at about midpoint. Stipital sclerite meets labial sclerite at dorsal end of lateral arm. Labial sclerite with dorsal arms well sclerotized, each widened medially and with lateral projection; ventral part visible but unsclerotized. Prelabial sclerite Y-shaped. Silk press visible but unsclerotized. Mandibles each heavy-based with very short blade without teeth meeting base at almost a right-angle. Labial and maxillary palpi each with one larger and one smaller sensorium. Antennal socket visible. Spiracle (Fig. 4) small with cup-shaped atrium about 0.012 mm deep by 0.008 mm wide opening into closing apparatus about 0.014 mm long and 0.006 mm wide. Skin densely covered with very small rounded protuberances and a few small spines.

Acknowledgments

The writer wishes to thank Dr. D. A. Ross for providing the log from which known parasites had emerged and for parasite and beetle emergence data; Mr. Jim Munro, student assistant, who dissected the log; and Mr. Derek Parkin who assisted with the illustrations. Mr. G. S. Walley, Entomology Research Institute, Ottawa, identified the parasites reared from the logs by Dr. Ross.

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BOOK REVIEW

The Life of Insects, by V. B. WIGGLESWORTH. A Mentor book, World Publishing Company, New York and Toronto. Pp. 383. \$1.50.

There are few indeed who are qualified to review the content of a book in his own field by Prof. Sir V. B. Wigglesworth. But with the appearance of his new and generalised paperback it is fair to appraise the format, and to speculate on where it may take its place amongst books of comparable price and scope.

The audience envisaged is said to be the customary interested reader or knowledgeable layman, but in point of fact the book would make nearly an ideal *modern* text for teaching introductory entomology. The arrangement demonstrates this to some extent. Twelve pages of preliminaries and acknowledgments are followed by 298 pages of text; then 32 pages of appendix which are really chapter 18, a very bare outline of taxonomy entitled *A Catalogue of Insects*; next 265 references by chapters to classic books and papers dated to 1962; a glossary of 176 terms; and 10½ pages of index. All this for a price tag about one-tenth that of the usual texts.

The illustrations deserve special mention. There are 36 half-tone plates, plus 16 in color which consist of 29 photographs of protective and warning coloration, mimicry, pigmentation, etc. All these are excellent. The 164 text figures, almost always on the appropriate pages of text, are judiciously chosen from basic works. All the old friends are represented:

Snodgrass, Imms, Weber, Berlese, von Frisch, Pesson, Metcalfe and Flint, Grasse, Knight, Wigglesworth himself of course, even Albrecht Durer and Shell Chemical! Their reproduction is never inadequate even if it is sometimes less than perfect, but this is a small penalty for the low price. The effect was to make my mouth water for the hardback edition, presumably on better paper.

Those who heard Sir Vincent lecture or who met him when he attended our annual dinner in March, 1967, will recall with pleasure how lightly he wore his immense learning and how completely un-stuffy he was. These qualities come through in the non-pedantic writing. It is limpid and economical, avoiding jargon and lightened by deft near colloquialisms. He writes of evolutionary changes in the feeding habits of insects accompanied by changes in the cutlery used for feeding; the lower lip in Hemiptera is deeply grooved to sheath the business part; Homoptera have a beak; some organs are sausage shaped; a freshly molted cockroach if trodden on may pop like a burst balloon; *Dytiscus* beetles consume their pre-digested prey as a uniform soup; and so on.

This is the best general text I have seen since Imms', "Insect Natural History" of 1947. It is superior in its approach through physiology and it covers more ground geographically and scientifically.

—H. R. MacCarthy

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Contributors of papers on laboratory studies should use the metric system exclusively. Use of the metric system in reporting the results of field studies is a desirable ultimate objective. Since it is difficult to replace immediately such standard concepts as lb/acre by the unit kg/hectare, yards by meters, or miles by kilometers, the following table of conversion factors is presented.

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1 yard=0.914 m	1 acre=0.405 hectares	1 m=3.28 ft=1.094 yards
1 mile=1.61 km	1 lb/acre=1.12 kg/hectare	1 km=0.621 mile
1 lb.=453.6 g	1 lb/in ² (psi)=70.3 g/cm ²	1 kg=2.2 lb
1 gal (U.S.)=3.785 liters	1 lb/gal (U.S.)=120 g/liter	1 liter=0.264 gal (U.S.)
1 gal (Imp)=4.546 liters	1 lb/gal (Imp)=100 g/liter	1 liter=0.220 (Imp)
	1 dm ³ =0.0353 ft ³	
	1 hectare=2.47 acres	
	1 kg/hectare=0.89 lb/acre	
	1 g/m ² =0.0142 psi	
	1 g/liter=0.83 lb/100 gal (U.S.)	
	=1000 ppm	
	1 g/liter=1 lb/100 gal (Imp)	



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UNACCEPTABILITY OF CULTIVARS OF Highbush
Blueberry by Adult Black Vine Weevils
(Col.:Curculionidae)¹

W. T. Cram

ABSTRACT

When isolated adults of the black vine weevil, *Otiorhynchus (Brachyrhinus) sulcatus* (F.), were fed highbush blueberry foliage at constant 20°C and 16 hours photoperiod, the related cultivars Cabot and Weymouth were unacceptable, whereas Jersey, Rancocas, June, Pemberton, Bluecrop, Rubel, Dixi and Stanley were acceptable, judged mainly on weight gains, feeding rates, fecundity, and survival. The presence of a feeding deterrent is indicated in the two unacceptable cultivars but other possibilities are a lack of some necessary nutrient(s) or an imbalance or unavailability of nutrients which may invoke the response of inadequate feeding. Adults appear to die from starvation.

INTRODUCTION

The black vine weevil, *Otiorhynchus (Brachyrhinus) sulcatus* (F.), (Zimmerman, 1968), a parthenogenetic European species, occurs on many species of plants and is a major pest on several economic crops, and many ornamentals such as strawberry, cranberry, blueberry, yew, cyclamen, and azalea. These plants are obviously different in many respects and represent a broad range of acceptability by the pest. In earlier studies on the acceptability of plants found in peat bogs where highbush blueberry is grown, Cram and Pearson (1965) found that excised leaves from certain weeds were more efficient sources of food for the adults than blueberry itself. These results led to a study of the acceptability of leaves from several highbush blueberry cultivars grown in peat bogs near Vancouver, British Columbia.

MATERIALS AND METHODS

The general methods were the same as those described earlier (Cram and Pearson, 1965). Besides collecting newly emerged adults in the field, mature larvae were collected from soil under blueberry bushes in late May, and placed singly in holes made with a planting board in a standard greenhouse flat containing peat soil from the collection site. The holes were covered lightly, the soil was watered as required, and the larvae were allowed to pupate and the adults to emerge in the laboratory. In this way adults were obtained which had never fed on foliage. Adults were prevented from escaping from the open flats by stapling a strip of polyethylene film around the outside of the flat. This strip extended about 2 cm above the top of the flat and the inside surface was

coated with fluon² applied with a swab of plastic foam.

Recently an improved method was devised for measuring the relative area of leaf consumed. After feeding a leaf was placed on a glass plate over graph paper with dots marked at alternate millimeter intersects. The area of leaf consumed was determined by counting the dots that were visible within the feeding notches. Each dot was equivalent to 4 sq. mm of leaf area. Excretion was rated by examining the relative amount of frass in the vials. All experiments were conducted in commercial bench-top rearing cabinets³ at a constant 20°C and 16-hour photoperiod.

Studies in 1966

Newly emerged adults and all blueberry foliage were collected from the same farm. The cultivars tested, the mean weight gain in 3 weeks, mortality, and the mean of viable eggs from 10 weevils each for 13 weeks appear in Table 1. The adults lost weight

Table 1. Response of adults of the black vine weevil fed excised leaves from highbush blueberry cultivars at constant 20°C and 16-hour photoperiod for 13 weeks.

Cultivar	Mean wt gain (mg) in 3 weeks	No. surviving to oviposit/13	Mean viable eggs
Weymouth	-5.4	0	0.0
Jersey	14.8	12	308.7
Rancocas	14.4	12	313.1
June	13.5	12	347.6
Pemberton	18.0	13	392.5
Bluecrop	17.6	13	449.0

¹ Contribution No. 183, Research Station, Canada Agriculture, 6660 N.W. Marine Drive, Vancouver 8, British Columbia.

² Fluon is a polytetrafluoroethylene dispersion manufactured by Imperial Chemical Industries, Welwyn Garden City, Herts. U.K.

³ Manufactured by Sherer-Gillett, Marshall, Michigan, U.S.A.

and died even before eggs could be laid when they were fed on Weymouth, but the other cultivars were all acceptable and there were no significant differences in the weight gains or eggs laid.

Table 2. Response of adults of the black vine weevil fed excised leaves from highbush blueberry cultivars at constant 20°C and 16-hour photoperiod for 10 weeks. Leaves from 4 farms to offset any local effects.

Cultivar	Farm ¹	Mean wt gain (mg) in 3 weeks	No. surviving to oviposit/13	Mean viable eggs ²
Weymouth	A	-4.6	0	0.0 a
Weymouth	B	-4.5	0	0.0 a
Weymouth	C	-2.4	1	29.4 ab
Weymouth	D	1.2	3	2.7 a
Cabot	A	-6.4	0	0.0 a
Cabot	D	-7.6	0	0.0 a
Rubel	A	9.6	10	229.9 d
Rubel	B	14.2	11	101.4 bc
Rubel	C	15.4	12	171.1 cd
June	C	11.4	12	239.5 d
June	D	13.6	12	176.9 cd
Dixi	C	15.3	13	230.4 d
Stanley	D	15.0	12	247.0 d

¹ A — Erickson; B — Illis; C — Blue Boy; D — Makara.

² Mean of 10 randomly selected survivors. Means sharing the same letter are not significantly different ($p = .05$).

Studies in 1967

The preliminary results of 1966 stimulated interest in other cultivars, especially any that were genetically related to Weymouth. The cultivar Cabot is one parent of Weymouth, June is the other and

Rubel is a grandparent (Moore, 1966). In 1967 newly emerged adults from the fields and leaves from the different cultivars were collected from more than one farm to offset any local climatic or soil effects. The mean weight gain in 3 weeks, the number of laying eggs, and the mean of viable eggs for 10 randomly selected weevils for 10 weeks appear in Table 2. The unacceptable nature of Weymouth was again evident and its parent Cabot also produced a similar response. Leaves from different farms did not alter this response significantly. The cultivars Rubel, June, Dixi and Stanley were all acceptable on the basis of the parameters measured.

Another series was observed to show the response to Cabot and Stanley using adults that had fed on strawberry foliage since emergence. These were all ovipositing at a high rate. Ten individuals were then fed on Cabot, on Stanley or continued on strawberry (Northwest). Those on strawberry and Stanley continued to oviposit at normal, comparable levels, whereas there was a sharp reduction in oviposition in those on Cabot (Table 3).

Studies in 1969

To clarify and substantiate the earlier findings, studies were concentrated on one acceptable cultivar, Stanley, and one unacceptable cultivar, Cabot. Leaves from both were collected at the Makara farm. All adults were from larvae collected in the field and allowed to pupate and emerge in the laboratory. Emphasis was on the weight change, amount of feeding and fat content of individual adults fed for 2, 3, 4 and 5 weeks at a constant 20°C and at a 16-hour photoperiod. When the adults emerged from the soil they were weighed, and assigned to a cultivar and a time period. In this way 34 unfed adults from every date within the 10-day emergence period were included in each time period. Adults were fed at weekly

Table 3. Response of 13 actively ovipositing adults of the black vine weevil fed at first on strawberry then changed to the blueberry cultivars Cabot or Stanley or continued on strawberry at constant 20°C and 16-hour photoperiod.

Host	Mean viable eggs/week							Mean eggs /week
	Weeks after change							
	1	2	3	4	5	6	7	
Blueberry								
Cabot	6.9	14.8	5.0	2.6	0.3	2.6	13.5	6.5
Stanley	40.7	13.2	28.5	32.3	26.2	31.8	38.4	30.2
Strawberry								
Northwest	13.2	30.3	40.9	34.1	52.8	37.5	28.7	33.9

intervals as before. When their assigned time period had elapsed they were weighed, killed in ethyl acetate vapour, weighed again, dried at 90° C for at least 48 hours, weighed, extracted, dried, and finally weighed. The extraction was similar to the method of Nijholt (1967) and was accomplished by placing a single dried adult with its numbered label in a small extraction thimble which was stoppered with a loose plug of glass wool. Nine thimbles were placed in a large soxhlet extractor and extracted with petroleum ether for at least 7 hours. Tests revealed that longer periods did not result in further extraction of petroleum ether solubles.

Significant differences ($p = .05$) between the cultivars were recorded for weight changes, feeding, excreting, moisture and fat contents (Table 4). After 5 weeks 31.4% of the weevils were dead on Cabot but only 5.7% on Stanley. The effect of Cabot was evident within the first 2 weeks of feeding when all parameters but fat content were significantly different. The fat contents after 2, 3, 4 and 5 weeks on Cabot were significantly lower than after only 3 weeks on Stanley. The effect of Cabot appears to be related to the presence of an unknown feeding deterrent, since feeding, although normal at first, soon changes to an atypical small notching or tasting

of the leaf edge rather than the normal, deep and large notching observed on acceptable cultivars. Under the conditions of these experiments even the Cabot foliage that was consumed was: not sufficient to sustain the normal growth of the fat body and the immature reproductive system (Cram, 1958); or all the necessary nutrients were not present; or they were present in a form that was not readily available to the weevil; or they were present in unbalanced concentrations. Gordon (1961) says that in general, nutritionally adequate foods induce feeding and inadequate foods do not. Therefore, in this instance, there may not be a chemical deterrent but rather the negative response might be due to nutritional inadequacy. The exact cause of the unacceptability of Weymouth and Cabot has not been found despite many attempts to establish a qualitative or quantitative difference in the chemical composition of the leaves. The effect of varying the temperature regimes sheds some light on these observations (Cram, 1970).

Acknowledgements

The help of Mr. W. D. Pearson, Mr. R. Hlatky and Mrs. Susan Burt, while serving as student assistants, is gratefully acknowledged.

Table 4. Response of adults of the black vine weevil fed excised leaves from the blueberry cultivars Cabot or Stanley for 2, 3, 4 or 5 weeks at constant 20° C and 16-hour photoperiod.

Cultivar	No. adults	Weeks of feeding	Mean wt gain (mg) ¹	Mean feeding /week (Sq mm of leaf)	Mean frass /week ²	Mean % moisture	Mean % fat ³	% Mortality
Cabot	34	2	-5.3 a	182.0 a	1.3 a	76.8 a	8.4 ab	5.6
	31	3	-6.6 a	158.2 a	1.6 b	76.6 a	6.8 a	13.9
	31	4	-6.3 a	144.0 a	1.4 ab	74.8 ab	8.1 ab	8.6
	24	5	-6.7 a	138.8 a	1.6 b	73.5 b	8.5 ab	31.4
Stanley	34	2	6.4 b	346.6 b	2.4 c	68.6 c	13.0 bc	5.6
	35	3	8.8 bc	324.1 b	2.7 d	64.2 d	15.8 c	0.0
	31	4	11.2 c	335.2 b	2.2 c	57.7 e	17.6 c	2.8
	33	5	11.9 c	318.7 b	2.5 c	55.8 e	18.3 c	5.7

¹ Means sharing the same letter are not significantly different ($p = .05$).
² Rated as amount of frass in vial.
³ Petroleum ether solubles. Mean of 34 freshly transformed adults was 5.3%.

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ACCEPTABILITY OF CULTIVARS OF Highbush BLUEBERRY AT VARYING TEMPERATURES BY ADULT BLACK VINE WEEVILS (COL.:CURCULIONIDAE)¹

W. T. CRAM

ABSTRACT

Adults of the black vine weevil, *Otiorhynchus* (*Brachyrhinus*) *sulcatus* (F.), fed and oviposited at normal, expected rates when fed excised foliage of the acceptable highbush blueberry cultivars, June and Stanley, in variable temperature regimes of 7 to 15, mean 10; 12 to 19, mean 15; and 16 to 29, mean 22°C. However, on the unacceptable cultivars, Cabot and Weymouth, they laid some eggs at the high and very few eggs at the medium regimes, whereas in earlier work they laid no eggs at a constant 20°C. These results indicate that Cabot and Weymouth provide barely adequate nutrition to the weevils and that environmental stresses such as a constant 20°C demand more nutrients than the unacceptable cultivars can provide. Variable conditions, probably due to a lower turn-over rate during the cool periods, allow the insect to obtain the nutrients necessary for fat body development and some oviposition.

INTRODUCTION

A clear pattern of unacceptability of the highbush blueberry cultivars Cabot and Weymouth to adults of the black vine weevil, *Otiorhynchus* (*Brachyrhinus*) *sulcatus* (F.), was shown at the constant laboratory conditions of 20°C and 16 hours photoperiod (Cram, 1970). Further tests at three variable temperature regimes were conducted to see if this response also occurred in somewhat more natural environmental conditions.

MATERIALS AND METHODS

The general methods were the same as those described earlier (Cram and Pearson, 1965). One half of the adults in each series was collected in the field, the rest were collected as mature larvae and allowed to transform to adults in the laboratory. Ten adults per treatment were observed for 13 weeks. The cultivars tested were the unacceptable Cabot and Weymouth, and the acceptable June and Stanley (Cram, 1970). All foliage was collected from the

Makara farm.

The temperature regimes were selected to approximate a cold, a cool or a hot summer. The regimes were attained by setting the electronic programmer on three bench-top growth cabinets (Sherer-Gillett, Marshall, Mich., U.S.A.) to hourly settings which produced acceptable temperature curves with daily temperatures of 7 to 15, mean 10; 12 to 19, mean 15; and 16 to 29, mean 22°C. The photoperiod was kept at 16 hours. From six randomly selected survivors per cultivar per regime, data were collected on weight change in three weeks, preoviposition period, number ovipositing and numbers of total and viable eggs after eight weeks from the first egg.

These data were analyzed by computer and the egg data were found to be highly heterogeneous often with significant interaction between regimes and cultivars, thereby invalidating the very highly significant differences between the three regimes and between the two sets of cultivars. For this reason, significant differences are not given in Table 1, but examination of the means indicates the trends.

¹ Contribution No. 184, Research Station, Canada Agriculture, 6660 N.W. Marine Drive, Vancouver 8, British Columbia.

TABLE 1. Response of adults of the black vine weevil fed excised leaves of highbush blueberry cultivars at 3 variable temperature regimes.

Cultivar	Temperature regime ¹	Mean wt change (mg) in 3 weeks ²	Mean pre-oviposition period-days ²	No. of 6 actually laying eggs	Mean total eggs ³	Mean viable eggs ³
Cabot	Low	-1.5	-	0	0.0	0.0
	Med.	-2.4	58.0	2	4.0	3.0
	High	4.2	41.2	6	147.2	24.5
Weymouth	Low	-4.1	-	0	0.0	0.0
	Med.	1.9	58.4	2	9.7	2.2
	High	6.0	39.5	6	188.2	40.0
June	Low	3.7	55.9	4	25.0	10.0
	Med.	7.5	34.7	6	76.8	47.7
	High	9.2	30.8	6	317.2	149.8
Stanley	Low	6.0	54.5	6	33.2	7.8
	Med.	4.9	40.7	6	101.8	67.8
	High	12.9	29.2	6	487.8	233.3

¹Low 7 to 15, mean 10; Med. 12 to 19, mean 15; High 16 to 29, mean 22°C.²No interaction effects; data from both temperature regimes and cultivars gave significant F values at $p = .01$ ³High interaction effects.

RESULTS AND DISCUSSION

The responses of the adults to the four cultivars at variable temperature regimes (Table 1) were different from those recorded earlier at a constant temperature of 20°C (Cram, 1970). Weight changes were significantly different between regimes and between cultivars. Adults lost weight on the unacceptable cultivars at low and medium regimes, but there was some weight gain at the high regime. Adults gained weight normally at all regimes on the acceptable cultivars. Preoviposition periods were also significantly different between regimes and between cultivars. On the unacceptable cultivars all six adults laid a few eggs at the high regime; two laid a few eggs at the medium regime; and no eggs were laid at the low regime. On the acceptable cultivars all six adults laid many eggs at the high regime, several eggs at the medium regime and some eggs at the low regime. These results indicate that the unacceptable cultivars are nutritionally adequate for oviposition but barely so and that the nutrients are not present in ratios or amounts suitable to class the cultivars as acceptable. One explanation for the response to a

constant temperature of 20°C may be that this unnatural regime forces the adults to such a high turnover rate that the levels of nutrients in Cabot or Weymouth do not provide the reserves necessary for growth of the fat body and ovaries prior to oviposition; thus the adults actually lose weight. This inadequate diet might also cause a reduction in feeding rate as suggested by Gordon (1961). At variable regimes the cooler nights may result in a slower turn-over rate allowing the normally nocturnal adult to accumulate reserves.

The low temperature regime approaches the 8 to 15°C range which was tested earlier for strawberry (Cram, 1965) and was found to result in a low oviposition rate similar to the results with acceptable blueberry cultivars. The effect here is undoubtedly related to temperature alone.

The wide difference between total and viable eggs recorded for all regimes and cultivars is not understood. Usually viability is well above 80 per cent.

Acknowledgement

The help of Mr. R. Hlatky, while serving as a student assistant, is gratefully acknowledged.

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EFFECTS OF SPRINKLER IRRIGATION ON McDANIEL AND EUROPEAN RED MITES IN APPLE ORCHARDS¹

WILLIAM B. HUDSON and B. P. BEIRNE²

ABSTRACT

Overtree sprinkler irrigation of apple trees was effective in keeping populations of McDaniel spider mites, *Tetranychus mcdanieli*, below the economic level. Sprinkling had less effect on European red mites, *Panonychus ulmi*, because the females moved to the undersides of the leaves and continued egg-laying during the sprinkling and because the eggs, unlike those of *T. mcdanieli*, were not dislodged by the sprinkling. The effectiveness may be increased by timing the sprinkling to coincide with the first appearance of the immature stages and by increasing the size of the droplets.

INTRODUCTION

Major innovations in orchard management rapidly being adopted in the apple-growing areas of British Columbia and Eastern Washington are integrated programmes for pest damage control and permanent overtree sprinkler systems for irrigation. These two are interrelated because the sprinkling must be a part of any integrated control programme and may be appropriately modified if it affects pests.

This paper summarizes some results of surveys and experiments aimed at answering two questions in relation to the chief pest mites: has overtree sprinkling a significant effect on their populations; and, if it has, how might the effect be modified? The species discussed here are the most important pest mites: the McDaniel spider mite, *Tetranychus mcdanieli* McGregor, and the European red mite, *Panonychus ulmi* Koch. The work was done in orchards in the Yakima district of Washington State in 1968 and in the South Okanagan district of British Columbia in 1969.

Various published records indicate the likelihood that orchard mite populations are affected by irrigation sprinklers. Recent popular reports claim that overtree irrigation has a control effect (Ross, 1968; Stark, 1969; earlier records indicated that the mechanical effects of orchard sprays could reduce mite populations substantially (Frost, 1924; Newcomer and Yothers, 1927; Spuler, 1930; Moore *et al.*, 1939, Chaboussou, 1961); and there are references to rain washing mites from leaves (McGregor, 1914; Ross and Robinson, 1922; Garman, 1923; Frost, 1924; Hamilton, 1924; Garman and Townsend, 1938; Kuenen, 1945; Linke, 1953). The work described here shows that overtree sprinkling has a significant control effect on

the populations of both species but normally exerts economic control only on the McDaniel mite (Hudson, 1970).

EFFECTS OF COMMERCIAL SPRINKLER SYSTEMS

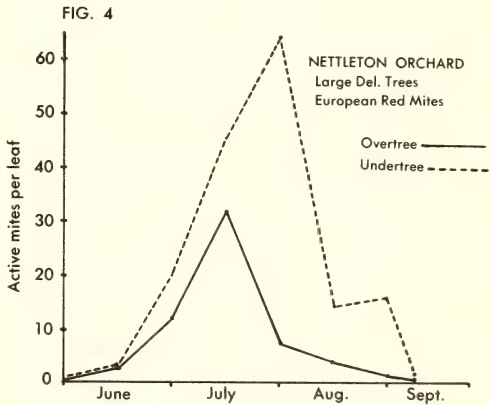
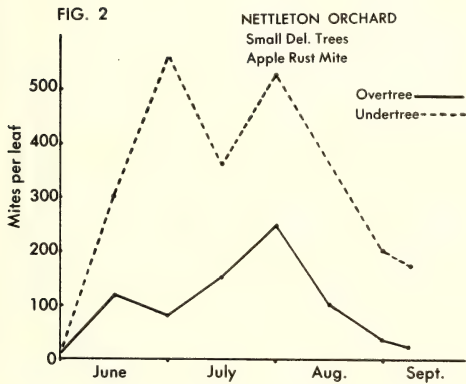
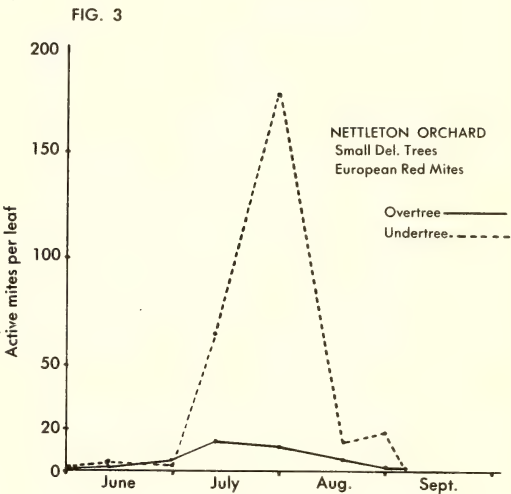
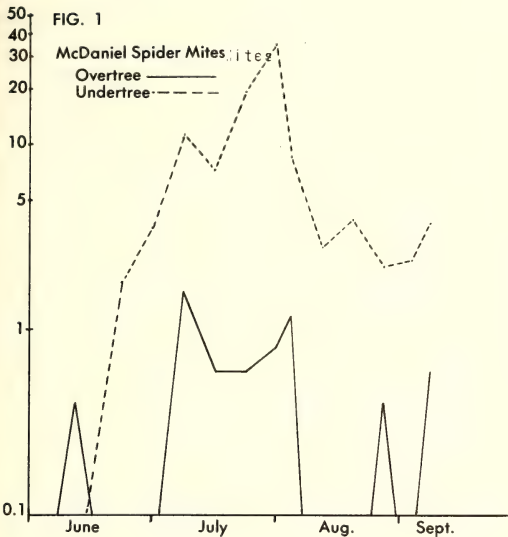
The effects of overtree and undertree sprinkling on populations of the McDaniel mite were investigated in an orchard at Yakima, Washington. Half the orchard was irrigated by one system and half by the other. Changes in the mite populations were determined by counting the number of mites per leaf on each of ten leaves from the same marked limbs on each of five trees every two weeks during June and every week thereafter until early September.

Results are shown in Fig. 1. It was evident that populations of the McDaniel mite were kept below injurious levels when the trees were irrigated by overtree sprinklers on a normal schedule. In the overtree-sprinkled block the average number of mites per leaf (of 14 samples) was 0.4 and the highest number 1.6 whereas in the undertree sprinkled block the average was 7.3 and the highest 35. There was visible leaf injury to many trees in the undertree sprinkled block but not in the overtree sprinkled one. In an experimental orchard at Summerland, B.C., the mite populations increased by 1.04 and 0.4 times over the pre-treatment counts on two sprinkled trees in six weeks but 17.2 and 11.3 times on two control trees.

Surveys using the same procedures in the Nettleton orchard at Naramata, B.C., showed the effects of sprinkling on populations of the European red mite. Again it was evident that overtree sprinkling was much more effective than undertree sprinkling in reducing populations. The results are shown in Figs. 3 and 4. However, the mites reached injurious population levels in both blocks and chemicals had to be applied to prevent economic damage. Despite this, foliage injury was moderate to severe on all trees of the undertree-sprinkled block.

¹ Part of a thesis submitted by W. B. Hudson for the degree of M.S. of Simon Fraser University. Details of methods and data may be obtained from him at: Yakima County Cooperative Extension Service, 233 Courthouse, Yakima, Washington, U.S.A.

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Figs. 1-4. Effects of overtree versus undertree sprinkling on populations of: (1) McDaniel mite at Yakima, Wash.; (2) apple rust mite at Naramata, B.C.; (3 and 4) European red mite at Naramata.

Surveys using the same procedures in a third commercial orchard, at Summerland, gave results for both species that agreed in general with those at Yakima and Naramata. The conclusion is that an overtree sprinkling system operated on a normal irrigation schedule can by itself prevent economic harm from the McDaniel mite but not from the European red mite. The greatest reductions of both species were from the upper surfaces of the leaves; mites on the lower surfaces were less affected.

REASONS FOR DIFFERENT EFFECTS

Experiments with detached leaves indicated why the European red mite is less affected than the McDaniel mite by overtree sprinkling. The numbers, stages and distributions of mites on the same leaves were determined before and after exposure to field sprinkling. Three main differences between the two species were revealed:

Egg removal. Sprinkling washed the eggs of the McDaniel mite from the upper surfaces of leaves but not the eggs of the European red mite. Two h of sprinkling removed 90% of the eggs of the McDaniel mite and 24 h 99% but eggs of the European red mite were not washed off irrespective of the duration or intensity of the sprinkling.

Female migration. Many females of the European red mite escaped by migrating from the upper to the lower surface of the leaf when sprinkling began. They were affected similarly by rain and dew. In one experiment the number of females decreased from 203 to one on the upper surfaces of five leaves but increased from 82 to 128 on the lower surfaces. In another experiment the corresponding figures were from 205 to 174 and from 112 to 164. No such changes were observed for the McDaniel mite; there was no evidence that females migrated to the undersurfaces of the leaves when sprinkling started. In one instance the numbers of active mites increased by about 20% on the lower surfaces but this was attributed to eggs hatching and not to migration because the increase on control leaves was 37%.

Egg-laying. Sprinkling did not prevent egg-laying by the European red mite. The decreases in egg numbers following sprinkling were insignificant in most tests and could have been accounted for by hatching. In other tests the numbers increased, which indicated that egg-laying may increase during sprinkling. During one 12-h sprinkling period the eggs increased 26% on the sprinkled leaves but 6% on the control leaves. In another instance the average number of eggs per leaf on 20 leaves was 246 before 10-h of intermittent sprinkling and 436 after. No evidence indicated that egg-laying by the McDaniel mite increased during sprinkling. In one test the number of eggs on the lower surfaces of five leaves was 221 before sprinkling, 228 after 2 h and 192 after 24 h.

POSSIBLE IMPROVEMENTS

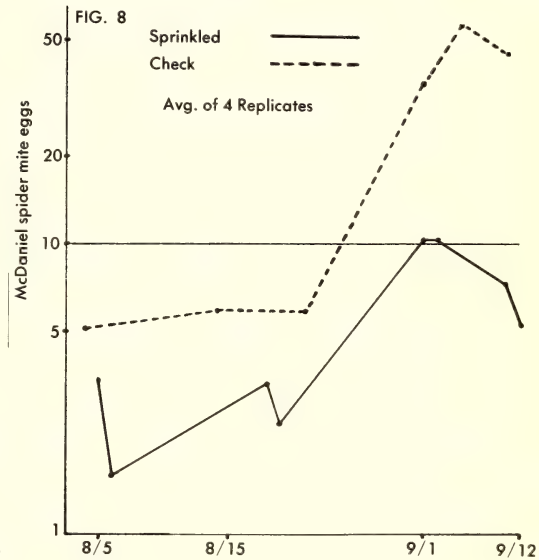
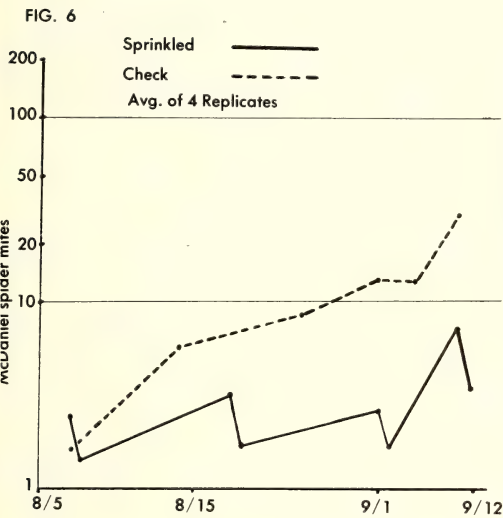
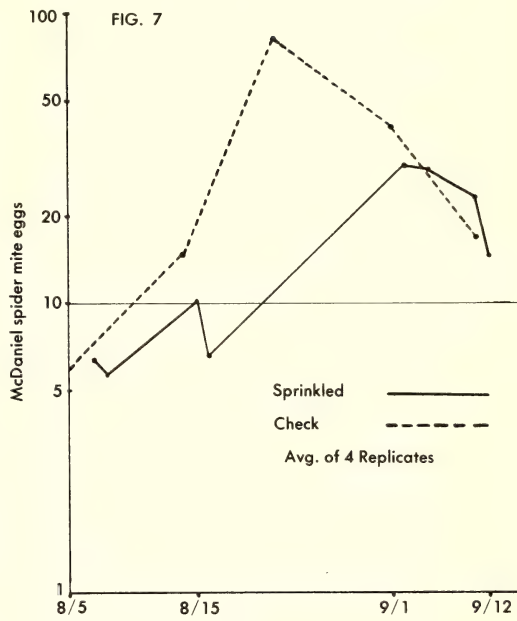
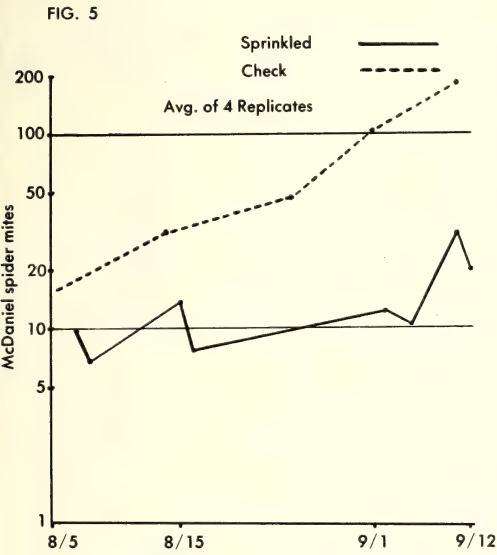
Commercial overtree sprinkler irrigation reduced populations of both species of mites. Counts showed that the usual reduction caused by a single sprinkling was 40 to 60% for both species. A reduction of 60% or less is not sufficient to prevent economic damage by the European red mite because of the high rate of survival of its eggs and females and its ability to oviposit during the sprinkling. Moreover, there are local variations in the habits of mites that vary their susceptibility. Thus, the strain of McDaniel mite in the Yakima district occurs more often on the upper surfaces of the leaves and spins more webbing than does the strain in the Summerland district, where the species tends to be less susceptible to harm by sprinkling that it does around Yakima. Any modification of the sprinkling system that would increase the mortality above the present normal maxima of about 60% for both species would be advantageous.

To explore the possibilities, tests were made in an experimental orchard at Summerland, using a portable overtree sprinkling system. Here the duration, timing, and concentration of the sprinkling and other controls were determined by the experimenter instead of by the grower. Some of the tests used the same procedures as in commercial orchards; others used single leaves. This series also showed that the effects on the apple rust mite, *Aculus schlechtendali* (Napela), were in general similar to the effects on the McDaniel mite. Fig. 2 is given as an example.

Rates of application. Results of conventional (0.3 inches/h) and of high (0.7) rates of application of water by overtree sprinkling were not significantly different for active stages of the McDaniel mite (Figs. 5 and 6) or for the eggs (Figs. 7 and 8). But there were slight differences with the European red mite in that 12 h of overtree sprinkling at 0.3 inches h reduced populations by about one-third whereas 12 h at 0.7 inches h reduced them one-half.

Coverage. Mites on the undersides of leaves were little affected by overtree sprinkling. Control would be increased if the undersides could be wetted. This happened when a test was conducted in a windstorm that carried the sprinkler water nearly horizontally. The percent control was greater than from any other single sprinkling. This indicates the possible effectiveness as a pest control agent of a power water spray.

Overtree sprinkling reduced the mite populations on leaves of the upper limbs more than it did on the lower. The average number of females on 20 upper leaves on each of two trees was reduced from 4.3 per leaf to 2.1, but on the lower leaves from 9.8 to 7.4.



Figs. 5-8. Effects of conventional rates of sprinkling (Figs. 5, 7) and of high rates (6, 8) on active stages and eggs of the McDaniel mite at Summerland, B.C.

Tree types. Surveys in the commercial orchard at Naramata showed that the average number of mites per leaf on 50 leaves was lower on small trees with overtree sprinklers than on large ones: 4.9 as compared with 7.3 with peaks of 14 and 31.4, respectively; but it was higher on small trees with undertree sprinklers than on large ones: 35.3 as compared with 20.3 with peaks of 178 and 64.

In the commercial orchard at Summerland overtree sprinkling was apparently more effective in reducing mites on Spartan than on Delicious apples, but this may have been because of varietal preference: mites are generally more of a problem on Delicious than on Spartan. The average number per leaf was 1.5 on Spartan and 4.5 on Delicious, with the highest numbers 3.0 and 16.2, respectively. The corresponding figures for undertree-sprinkled trees were 2.3 and 5.7 and 11.3 and 20.

Timing. Overtree sprinkling washes off a greater proportion of the immature stages of the European red mite than of the adults. Four h of sprinkling reduced adult populations by 54.9% (differences significant at the 5% level) but the immatures by 58% (differences significant at the 1% level). After 12-h of sprinkling the corresponding figures were 47% and 87%. The relative susceptibility of the immatures of this species to sprinkling and the immunity of the eggs suggests that for maximum control overtree sprinkling should be timed to affect the larval and protonymph stages of the first summer generation, after the overwintered eggs have hatched but before

the adults have developed. Results of experiments suggested that sprinkling to control the McDaniel mite should begin when the mite population is still low; it will then be kept low. There were indications that at high population densities control by sprinkling may be nearly offset by the rapid rate of increase of the mites.

CONCLUSION

It is clear that overtree sprinkler irrigation contributes to the suppression of populations of phytophagous mites. It does so without added cost to the grower, without harming the environment, and, so far as existing information indicates, without favouring other orchard pests or diseases. The effectiveness of an overtree sprinkler system in controlling mite populations may be increased, if sprinklings are timed to coincide with the first appearance of the immature stages, if the water droplets are as large as possible, and if the sprinklers are so arranged that every part of the tree is drenched.

Acknowledgements

The authors wish to thank the staff of the Canada Department of Agriculture's Research Station, Summerland, B.C., and in particular C. V. G. Morgan, for continuing cooperation and assistance during the work in the Okanagan Valley. The work was made possible by an operating research grant to B. P. Beirne from the National Research Council of Canada.

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OBSERVATIONS ON *RHAGOLETIS INDIFFERENS* AND RELATED SPECIES IN THE OKANAGAN VALLEY OF BRITISH COLUMBIA

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ABSTRACT

The western cherry fruit fly, *Rhagoletis indifferens* Curran was first recorded in the Okanagan Valley of British Columbia in 1968, and trapping during 1969 established the presence of this species in most of the cherry growing district in the region. *R. indifferens* emerges as an adult in early June, and flies continue to appear until mid-July. The principal host of this species, *Prunus emarginata*, Dough. was not found in the Okanagan, and no flies were found on *Prunus virginiana demissa* (Nutt.) which has been reported as a host.

A comparison of lures to trap the flies showed that ammonium carbonate traps were more efficient than yellow sticky boards or glycine-lye bait pans. The sticky boards, however, seem to be adequate for determining the presence of cherry fruit flies.

In addition to *R. indifferens*, 5 other *Rhagoletis* were trapped in commercial cherry orchards. The common species were *R. zephyria* Snow, *R. ribicola* Doane, and *R. berberis* Curran. *R. fausta* (Osten Sacken) and *R. tabellaria* (Fitch) were trapped in very low numbers in a relatively few locations.

INTRODUCTION

The western cherry fruit fly, *Rhagoletis indifferens* Curran was recorded for the first time in the Okanagan Valley of British Columbia during the summer of 1968. This species has been present for several years on Vancouver Island and in the Kootenay district (Madsen and Arrand 1966). The black cherry fruit fly *Rhagoletis fausta* (Osten Sacken) is present in the Shuswap Lake area near Salmon Arm and was recorded in the Okanagan Valley during 1951 and 1965. These two infestations did not spread from the original source and only an occasional fly was found in subsequent seasons. A survey in 1969 established that *R. indifferens* was present in the Okanagan Valley from Vernon to Okanagan Falls, but no flies were found in the Oliver-Osoyoos district or in the Similkameen Valley.

The native host of the western cherry fruit fly is bitter cherry, *Prunus emarginata* Dough. and flies have also been reared from choke cherry, *Prunus virginiana demissa* (Nutt.) (Frick 1954). The presence of native hosts complicates the problem of controlling cherry fruit flies in commercial orchards because they provide a source of flies for reinfestation (Peters and Arrand 1968). Consequently, a research program was initiated in 1969 to determine if wild hosts supported cherry fruit flies in the Okanagan. In addition, data were obtained on the emergence of the western cherry fruit fly in infested orchards and a comparison of various lures for trapping the flies was made.

MATERIALS AND METHODS

Wild hosts were surveyed for the presence of fruit fly larvae and collections from all suspect hosts were

Contribution No. 278. Research Station, Canada Agriculture Summerland, British Columbia.

¹ Report on the cherry fruit fly survey in the Okanagan Valley 1969. Canada Department of Agriculture, Plant Protection Division, September 4, 1969. Mimeograph.

brought into the laboratory for rearing. Fruit from these hosts was placed on sandy soil, and the sand sifted for fruit fly pupae at a later date. Pupae were placed in containers with moist soil and held in cold storage (1.1°C) for 150 days. The containers were then brought into the laboratory and held at room temperature until the fruit flies emerged.

Fruit flies were trapped in the field with yellow sticky boards of a similar design to that described by Wilde (1962). These boards were compared with two other traps, an ammonium carbonate trap described by Frick (1954) and glycine-lye bait pans which have been used to trap the walnut husk fly, *Rhagoletis completa* Cresson (Barnes and Madsen 1963). The traps were observed at weekly intervals to determine when flies first emerged and the peaks of activity during the season. Traps were installed in two areas, one at Westbank and the other at Okanagan Mission where the original infestations were found in 1968. A number of *Rhagoletis* species were captured on the traps, and they were identified by wing patterns illustrated in the comprehensive paper on the Genus *Rhagoletis* by Bush (1966). All identifications were confirmed by the Insect Taxonomy Section, Entomology Research Institute, Ottawa.

RESULTS

Native Hosts: An extensive survey was made, but *P. emarginata*, the principal host of the western cherry fruit fly was not found in the Okanagan Valley. No fruit fly larvae were found in collections of berries from *R. virgiana demissa* and none were reared in the laboratory from the host. No adult fruit flies were trapped on yellow sticky boards hung in locations where this shrub was abundant. Indications are that the western cherry fruit fly does not occur on native hosts in the Okanagan Valley.

Fruit Fly Emergence: The first *R. indifferens* was trapped on June 4, and the peak of emergence was between June 13 and June 24. The last fly was taken on July 28. A comparison of *R. indifferens* emergence at two localities is illustrated in Figure 1.

There was little difference in emergence time at the two orchards, and the long emergence period indicates that commercial cherry orchards will need chemical protection for a minimum of 6 weeks. A total of 74 properties were trapped in the two areas, and *R. indifferens* was taken in 16 properties. Of these, 9 were commercial orchards and the others neglected or backyard trees.

Trap Comparisons: A trap consisting of a

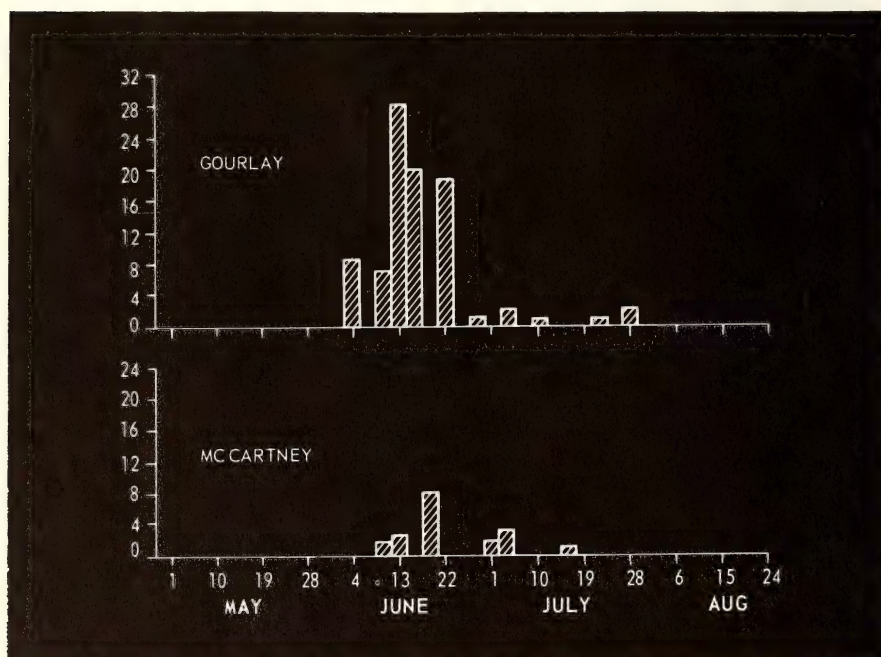


Fig. 1. The emergence of *R. indifferens* at two localities, Okanagan Mission (Gourlay) and Westbank (McCartney)

standard yellow sticky board with a wide mouth pint jar containing ammonium carbonate suspended underneath caught the most fruit flies. There was no difference in the catch between yellow sticky boards alone and the glycine-lye bait pans. These preliminary evaluations indicate that the ammonium carbonate traps might be useful in detecting very low fruit fly populations. The yellow sticky boards seem adequate for survey purposes and are easier to install and maintain than ammonium carbonate traps or glycine-lye bait pans.

Other *Rhagoletis* Species: In addition to *R. indiffrens*, 5 other *Rhagoletis* species were trapped during the season. The black cherry fruit fly, *R. fausta* was trapped in one locality, and only 4

specimens were taken. This species does not seem to compete with *R. indifferens* and this may explain the low population. *R. zephyria* Snow was common throughout the study area, and this species attacks snowberry, *Symphoricarpus albus* Blake, which is a common shrub in the Okanagan. Larvae were found in the berries and this species was reared from snowberry in the laboratory. *R. ribicola* Doane was trapped in most areas, with the majority of the flies from traps in backyard trees. The hosts of this species are currant and gooseberry, but no larvae were found in collections from these hosts. *R. tabellaria* (Fitch) was taken in a few localities and was the least common of the 6 species of fruit flies. The species is reported to attack the fruits of *Vac-*

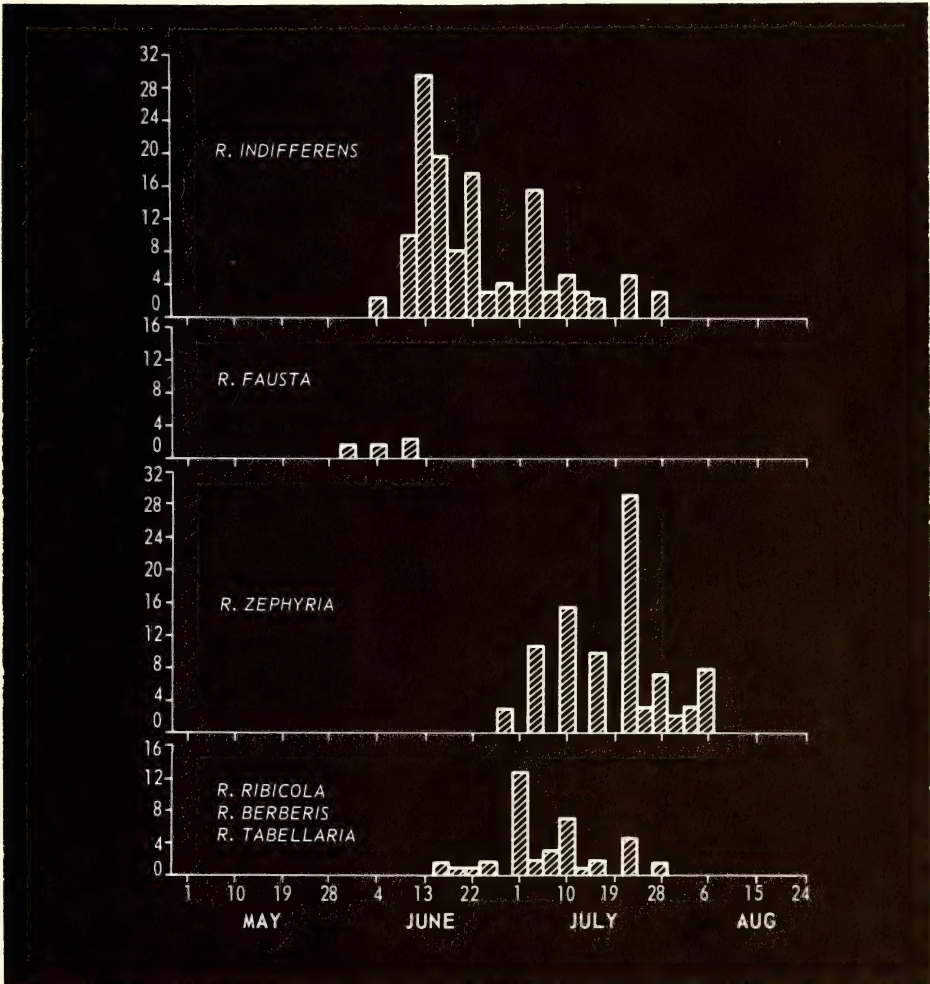


Fig. 2. Emergence of six species of *Rhagoletis* trapped on yellow sticky boards in the Okanagan Valley.

cinium, but no larvae were collected on this host in the Okanagan. *R. berberis* Curran was commonly encountered on traps and was recorded from nearly all the areas under study. *R. berberis* attacks the fruit of Oregon grape. *Mahonia nervosa* Pursh, and larvae were found in large numbers in the berries. Although pupae were readily obtained in the laboratory, adults did not emerge under laboratory conditions.

The emergence period of the six species of *Rhagoletis* trapped on yellow sticky boards is shown in Figure 2. *R. ribicola*, *R. berberis*, and *R. tabellaria* emerge at about the same period as *R. indifferens*, but the peak of emergence is about two weeks later. *R. zephyria* emerges later than the other species with peak emergence in mid-July. This adult activity coincides with the development of fruit on the snowberry plants. There were too few *R. fausta* taken to draw conclusions on adult emergence. In other areas, it appears earlier than *R. indifferens* and

the emergence period is shorter.

DISCUSSION

The lack of wild hosts for the western cherry fruit fly in the Okanagan Valley may mean that control of this major pest of cherries will be easier than in other areas. Trapping has shown that most of the flies occur in neglected trees, and the spraying or removal of these trees should significantly reduce fruit fly populations. Indications are that *R. indifferens* has been in the Okanagan for some time, since it is distributed over most of the cherry growing area. Yellow sticky boards seem to be reliable traps for determining whether chemical treatment is necessary. The presence of 6 species of *Rhagoletis* in the Okanagan indicates that the area is favorable for fruit fly development. Whether *R. indifferens* can become a serious pest in the Okanagan may depend on its ability to survive on cultivated cherries in the absence of a native host.

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NOTES ON DIAPAUSE IN THE TOMATO HORNWORM (LEPIDOPTERA: SPHINGIDAE), IN BRITISH COLUMBIA

F. L. BANHAM¹

INTRODUCTION

The tomato hornworm, *Manduca quinquemaculata* (Haworth), is a sporadic economic pest in commercial and home garden plantings of tomatoes in the southern dry-belt regions of British Columbia, particularly, in the Thompson, Okanagan and Similkameen Valleys (Banham and Arrand 1970). It also occurs on related Solanaceous plants, including egg plant, pepper and potato.

At Summerland, B.C., in 1968 and 1969, there were up to 2 generations of hornworms each year. First generation moths emerged about mid-June and second-generation moths about mid-August. As in

southern Ontario (McClanahan 1955), some moths did not emerge from first generation pupae until the following year. In the laboratory, 1 of 12 pupae and 2 of 17, respectively, diapaused from larvae collected in the field in late June or July in 1968 and 1969. Both years, moths emerged from the remainder of the non-diapausing pupae after about 3 weeks. Insufficient numbers of tomato hornworm larvae were collected and reared to indicate the actual incidence of facultative diapause in the pupal stage. In North Carolina, Rabb (1966), reported a facultative diapause in the pupal stage of the closely related tobacco hornworm, *Manduca sexta* (Johannson), with the incidence of diapause increasing from less than 5% in June to more than 95%

¹ Contribution No. 288. Research Station, Canada Department of Agriculture, Summerland, British Columbia.

in late fall. Diapause was initiated in the larval stage of the tobacco hornworm by photoperiodic day length cycles of 5 to 13 hours. In contrast, temperature rather than photoperiod was the major

factor influencing diapause induction in the tomato hornworm in southern Ontario (Svec, 1964). Diapause was induced by exposing prepupal and pupal stages to temperatures of 22°C or lower.

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INCONGRUITY BETWEEN LARVAE AND ADULTS IN THE ACCEPTABILITY OF Highbush BLUEBERRY CULTIVARS BY THE BLACK VINE WEEVIL

W. T. CRAM

Laboratory observations have shown that adults of the black vine weevil, *Otiorhynchus (Brachyrhinus) sulcatus* (F.), do not oviposit or survive when fed exclusively on excised leaves of the blueberry cultivars Cabot and Weymouth (Cram, 1970). To test the acceptability of 4 cultivars by

larvae, rooted cuttings were potted in peat soil and grown in the greenhouse. Twenty 8-day-old viable eggs were placed on the soil of each of 5 replicates. Fifteen weeks later the pots were dumped and the soil was searched for larvae with the following results:

Cultivar	Replicates					Total
	1	2	3	4	5	
Rancocas	0*	1*	4*	2*	0*	7
Pemberton	0	2*	3*	1	0	6
June	0	1*	0	0*	2*	3
Weymouth	5*	1	3*	0*	5*	14

*Plant dead-stem girdled below soil.

Although there was very low recovery of larvae the evidence of severe damage was present in all the cultivars. The largest number of late instar larvae were recovered from Weymouth which indicates that there is no congruity between the acceptability of this cultivar by larvae feeding on roots and adults feeding on leaves. Hence, from an economic standpoint,

Weymouth cannot be considered to be an immune cultivar. In practice, a heavy infestation of larvae severely damaged and even killed many young Weymouth plants in an 8-acre nursery row planting. Reproductively mature adults probably walked into the area and deposited their eggs around these plants.

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LARVAL DIAPAUSE IN *DENDROCTONUS OBESUS* (MANNERHEIM) (COLEOPTERA: SCOLYTIDAE)

E. D. A. DYER

ABSTRACT

Dendroctonus obesus (Mannerheim)¹ larvae diapaused in the last instar during laboratory rearing with warm thermoperiods reduced to 12 hours or less, mean temperatures of 50°-56°F. (10°-13.3°C) and at least one minimum subcortical temperature near or below the larval development threshold during the third and fourth instars. Larvae reared at constant temperature of 70°F (21.1°C) did not diapause. Prediction of beetle populations and forest damage is dependent on a knowledge of the seasonal meteorological conditions that affect larval diapause and subsequently the numbers of mature beetles capable of initiating attacks. Further investigation is required to determine the separate effects of brood age, temperatures and thermoperiods on diapause.

INTRODUCTION

The spruce beetle, *Dendroctonus obesus* (Mannerheim)¹, kills large volumes of white (*Picea glauca* (Moench) Voss) and Engelmann spruce (*P. engelmannii* Parry) in western North America (Massey and Wygant, 1954; Wood, 1963). In this region, only those beetles that have passed the winter as adults reproduce the next summer (Massey and Wygant, 1954; Knight, 1961). The development rate therefore has a direct effect on the number of adults capable of invading new hosts at any time during the following year. Warm seasons, in which subcortical temperatures are maintained above the threshold for larval development, provide an opportunity for most larvae to develop quickly, pupate and mature before winter. However, meteorological conditions with minimums below this threshold may prevent a high percentage of the larvae from pupating until the next spring (Dyer, 1969). A preliminary experiment was conducted to determine whether larval or prepupal diapause could be demonstrated in the laboratory by rearing *D. obesus* from eggs in logs, under various temperature conditions. The maximum and minimum range was chosen to simulate a late-summer climate in the field.

METHODS

One hundred and sixty pairs of reproductive adults were released on six freshly cut spruce logs. These produced about 5.3 attacks per square foot of bark. After 19 days at constant 70°F and 12 hours' light, the logs were separated at random into 3 pairs: A, B and C. C logs were held at constant temperature and daylength of 70°F and 12 hours until day 83. A and B were placed in an incubator where thermoperiods of 17 hours warm and 7 hours cool were commenced with maximum, minimum and mean temperatures as shown (Fig. 1). A daylength of 17

hours coincided with the warm thermoperiod. On day 27, the warm thermoperiod (and photoperiod) for A and B logs was reduced to 16 hours, on day 41, to 12 hours and on day 55, to 10 hours. On day 47, A and B logs were cooled to 30°F for 4 hours, resulting in a minimum subcortical temperature of 45°F, just above the larval development threshold of about 43°F (Dyer, *et al.*, 1968). On days 49 and 50, B logs were cooled to 19°F for 4 and 7 hours, respectively, with resulting subcortical temperatures of 29°F and 25°F. On day 83, A, B and C logs were held at 33°F for 5 days and then at 70°F until day 138, the end of the experiment.

Two half-square-foot samples of brood under the bark of A, B and C logs were examined on days 20, 28, 41, 55, 69, 83, 110 and 138. The total progeny per square foot and the per cent in each of seven stages of development were recorded at each date.

RESULTS AND DISCUSSION

Table 1 shows seven stages of brood as they occurred at each sampling date. By day 55, the majority of larvae in all logs had reached the last instar or had become pupae or adults. Ninety-nine per cent of the brood in C logs had become adults by day 69 without any pause in development. After this date the larvae in the B logs stopped development beyond the fourth instar; no more pupation occurred during the next 41 days even though, for most of this period, the temperature was much above the development threshold (Fig. 1, Table 1).

Some pupation commenced again during the last 28 days at constant 70°F, although about 40 per cent of the progeny in the B logs still remained larvae after 138 days (Table 1). The suppression of development just before pupation is characteristic of larval or pre-pupal diapause (Beck, 1968). In the B logs, the intense diapause commitment of the remaining larvae had continued after 50 days of exposure to constant temperature suitable for development.

¹ According to Wood, S. L., the name *D. rufipennis* (Kirby) now has precedence. Great Basin Naturalist 29 (3): 116, 121, 1969.

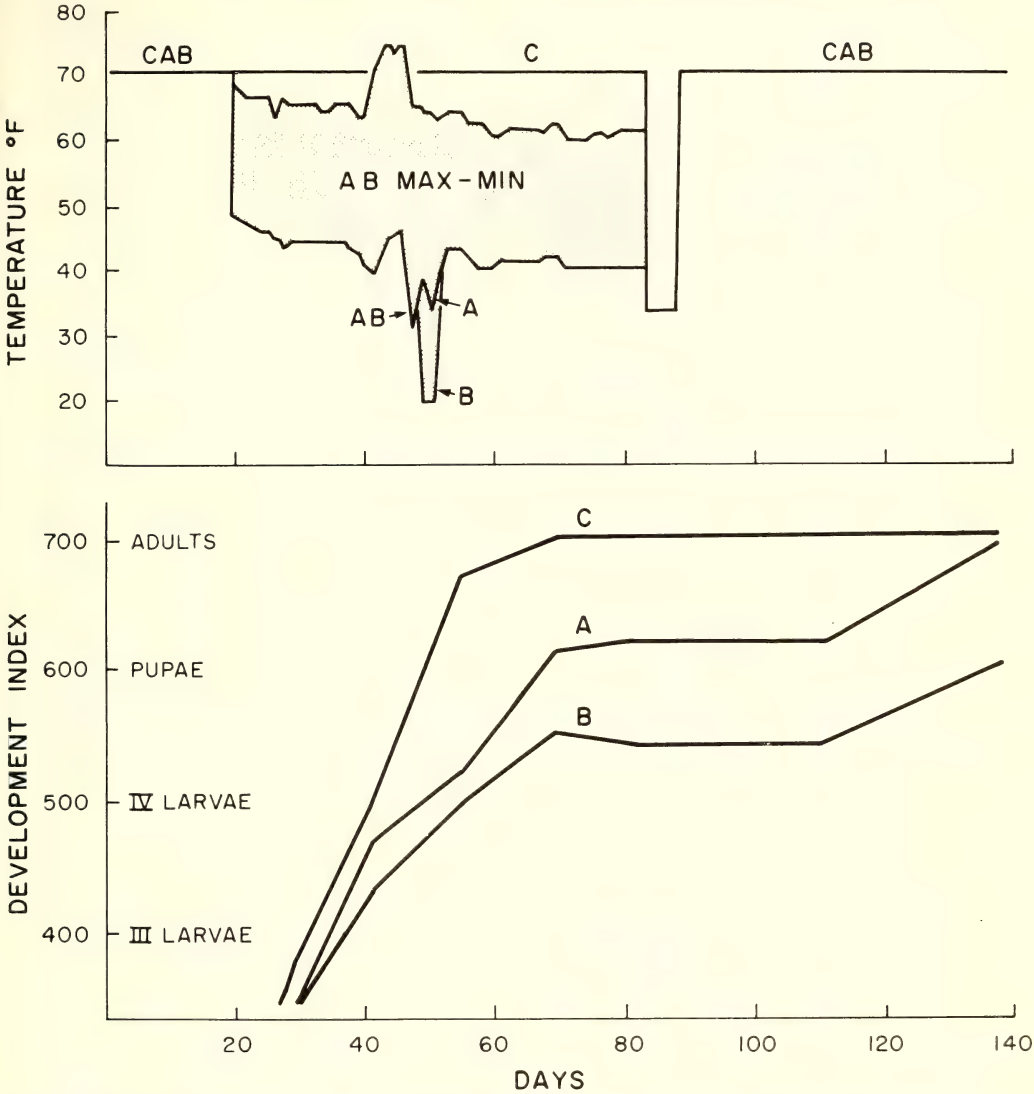


Fig. 1. Temperature regimes and corresponding development of *D. obesus* brood in logs C at constant temperature and logs A and B exposed to cooler diurnal thermoperiods with maximum and minimum range shaded.

Diapause in *D. obesus* larvae is likely to be determined by environmental conditions preceding the actual manifestation (Beck, 1968). It appears to be dependent on some combination of thermoperiod length, mean and minimum subcortical temperature, and stage of development when the critical diapause-inducing conditions occur. No diapause resulted when larvae were reared at a constant warm temperature (70°F). The mean and the minimum temperatures appeared to be related to the more intense diapause induction in broods of B logs than of A logs. The stage of development when the

minimum subcortical temperatures occurred might also have had some relation to the percentage of brood entering diapause, because larvae in A logs were slightly more advanced than those in B logs. Daylength or photoperiod seems unlikely to affect larval development under bark. However, in natural environments, thermoperiod is closely synchronized with photoperiod and may replace the latter in its effect on diapause induction. Beck (1968) reports that diapause in mature larvae of the European corn borer, *Ostrinia nubilalis* (Hübner), is induced by short-day photoperiods during larval growth, but its

Table 1. Development of *Dendroctonus obesus* brood occurring in two half-square-foot samples of bark from logs C at constant temperature and from A and B logs at cooler diurnal thermoperiods. Each stage is expressed as a percentage of the total progeny sampled.

LOGS	TOTAL PROGENY SAMPLED	DAY SAMPLED	EGGS	PER CENT BROOD			
				I	II	III	IV
C	170	20	35	7	58		
	179	28	5	2	19	66	8
	166	41				2	94
	124	55					4
	160	69					21
	151	83					0.5
	127	110					0.5
	54*	138					
A	312	20	29	30	41		
	185	28	16		18	66	
	205	41	5			14	80
	167	55				4	70
	174	69					26
	141	83					37
	159	110					35
	181*	138					8
B	312	20	56	18	26		
	201	28	8	2	41	49	
	222	41	7		7	30	56
	138	55			2	3	93
	119	69					2
	154	83					61
	154	110					30
	120*	138					9
							79
							82
							40
							18
							42

Samples taken on 0.5 to 0.75 sq. ft.

incidence is influenced by low temperature during the dark phase. He also points out that thermoperiod may, under some circumstances, substitute for photoperiod in determination of diapause. The Indian meal moth, *Plodia interpunctella* Hübner, requires an intermediate temperature (68°F) during the last two instars for 100 per cent induction of larval diapause. Higher temperature of 86°F is effective in averting diapause (Tsuji, 1963). Mansingh and Smallman (1966) show that complete induction of pupal diapause in *Hyalophora cecropia* Linnaeus and *Antheraea polyphemus* Cramer occurs following short-day (12-hour) photoperiod during the second last larval instar. Further experiments are required to determine the separate effects of mean and minimum temperature, thermoperiod length and brood age when diapause is initiated in *D. obesus*.

Larval diapause probably has survival value to bark beetle populations in very cold climates where severe cold might cause pupal mortality. Larvae which diapause in the autumn will pupate and become adults the following summer, but these adults will not attack new hosts until they have passed another winter. Thus, seasonal temperatures that induce a high percentage of larval diapause will delay for one year the potential of that population to damage trees.

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MALE RESPONSE TO FEMALES IN THE MARSH CRANE FLY, *TIPULA PALUDOSA* MG. (DIPTERA: TIPULIDAE)

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ABSTRACT

Laboratory and field experiments suggest that male *T. paludosa* receive a specific mating stimulus only in close proximity of a female. The anterior part of the female rather than the isolated abdomen is the source of the sex pheromone. Attempts to extract the material were unsuccessful.

INTRODUCTION

The biology and control of *Tipula paludosa* Mg. and its occurrence in North America have been reviewed by Wilkinson and MacCarthy (1967). In the field mating takes place immediately following the female's emergence which peaks about 11:00 p.m. and the eggs are mostly laid before morning (Coulson, 1962). Thus control by adult extermination is ineffective. The following preliminary experiments were intended to define the role of sex pheromone with a view to control by means of a metarchon (Wright, 1964).

METHODS AND RESULTS

Larvae collected in June and July 1969 were held in soil seeded with lawn grass. The pupae were sexed

and held separately in 30 x 30 x 30 cm cages in separate rooms under natural illumination but with supplementary light during the day from fluorescent lamps. An intact female pupa placed in a cage with ten unmated males was ignored until the first stage of emergence. Then mating attempts began and the males helped to dislodge the pupal integument. The pheromone was effective over a very short distance only as shown by the following experiments.

On five occasions, at different stages of the diel cycle of illumination, 1 to 3 unmated females (1-2 days old) were placed in a cylindrical cell (5 cm x 5 cm) with bronze mesh at each end. The cells were introduced into cages containing males and were ignored by them until the females were released when mating took place immediately.

A cylinder containing three females placed upwind of ten males in a wind tunnel (Kellogg and

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Wright, 1962) in an air stream of 25 cm-sec, elicited no male response. A female held by forceps, and brought progressively closer to an unmated male, produced a mating response only when the distance was reduced to about 1 cm.

The source of the pheromone was examined as follows: single males were confined overnight in 1-liter glass jars in darkness at 25 degrees C and 70 per cent R.H. and experiments were made in the morning by the light of a red photographic safelight. Using forceps, an isolated abdomen, the remaining head and thorax held by the wings, and an intact female were brought to within 1 cm of each male at 5 minute intervals. The results shown below, suggest that the source of the pheromone is in the forepart of the body.

Attempts were made to extract the active material from 10 unmated females with ether, alcohol, benzene or water containing a wetting agent. The extracts applied to 2 cm squares of filter paper or to female models failed to elicit mating response. Extracts from paper towels on which 20 females had been held for a week were likewise inactive.

Field experiments were made during August and September when wild *T. paludosa* adults were abundant. Traps made from half-gallon milk cartons, three baited with five males and three baited with five females were set three meters apart in a row in randomized order. In three days the traps baited with males caught seven males and one female while those baited with females caught six males. A second experiment used traps consisting of four 30 x 30 cm adhesive-coated vanes set at right angles and joined at the centre where a bronze mesh cell contained five males or five females. The total catch during a four-day exposure was 1,311 adult *T. paludosa* but the

ratio of 1 female to 4.6 males was the same in the traps baited with males as with females.

DISCUSSION

These experiments suggest that although a volatile emanation released by the female acts as a mating stimulant it is effective over a very short range and offers little hope of serving as an attractant to lure males into traps or onto a poisoned surface. However, in the absence or masking of this emanation it is probable that mating would not take place. Any substance which would pre-adapt the males by some kind of masking or fatiguing might be a useful means of control. Methods of achieving such interfering substances are under active development and have been reviewed by Wright (1970).

Mating attempts by virgin male *T. paludosa* caged for 30 sec. near intact females or their constituent parts, at 5-min intervals, on 2 days, were as follows:

Number of males	Mating attempts		
	Abdomen	Head and thorax	Intact female
4	0	4	4
6	0	4	6

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A CHRONIC INFESTATION OF MOUNTAIN PINE BEETLES IN LODGEPOLE PINE IN GLACIER NATIONAL PARK, MONTANA

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ABSTRACT

An infestation of mountain pine beetle (*Dendroctonus ponderosae* Hopk.) in lodgepole pine (*Pinus contorta* var. *latifolia* Engelm.) has been active since about 1950 in an area of 162 ha within Glacier National Park, Montana. Tree mortality is reported for 14 years. It fluctuated yearly, ranging from 0 to 4.7 trees per 0.405 ha (1 acre). Most trees above 25.4 cm in diameter had been killed by 1963.

INTRODUCTION

Mountain pine beetle (*Dendroctonus ponderosae* Hopk.) is a major pest of lodgepole pine trees (*Pinus contorta* var. *latifolia* Engelm.) in the western states. Its potential destructiveness was documented by Evenden and Gibson (1940). From 1927 to 1936, 57.75 million lodgepole pine trees above 7.62 cm in diameter were killed in an area of 543,453 ha in the Beaverhead National Forest, Montana. Outbreaks are usually of long duration and do not subside until most trees above a certain diameter (generally 15.2 cm) are killed.

An example of a tenacious mountain pine beetle infestation is discussed in this paper. It has been active since about 1950, but has not spread beyond 162 ha. This infested lodgepole pine stand is on the south-facing slope of Starvation Ridge north of Kintla Lake, Glacier National Park, Montana. The trees are about 60 years old and vary from 10.2 to 50.8 cm in diameter at breast height; the average d.b.h. is 22.9 cm.

Since 1954, surveys have been made annually to determine the number of trees killed within the infestation. Data were collected along 15 sample strips 20.1 m wide and up to 1,307.2 m long. The strips ran north and south, were 100.5 m apart, and sampled 31.9 ha of the infested stand. Table 1 shows the trees killed per 0.405 ha yearly from 1954 to 1967.

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Table 1. — Lodgepole pine trees per 0.405 ha killed annually since 1954 by the mountain pine beetle on Starvation Ridge, Glacier National Park, Montana

Year		Year	
1954	2.2	1961	0.4
1955	4.4	1962	0.9
1956	2.1	1963	0.4
1957	4.7	1964	0.5
1958	2.2	1965	0.0 ¹
1959	0.8	1966	0.2
1960	0.2	1967	0.9

¹ Only one infested tree was found on the sample strips.

It is interesting to note the even fluctuations in numbers of trees killed each year from 1954 to 1958. Woodpeckers fed heavily on 1957 and 1958 broods and probably caused the infestation to decline. A drought occurred in 1961 and the number of trees killed increased during 1962. By 1963, most trees over 25.4 cm d.b.h. had been killed. Droughts occurred again in 1966 and 1967, and an upward trend in the infestation followed. Approximately 7,960 lodgepole pine trees were killed by the mountain pine beetle in this area of only 162 ha between 1954 and 1967. No control action has been considered because the stand is in a remote area of the Park which does not receive or make much public impact.

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DERMACENTOR TICKS ON WILDLIFE AND NEW RECORDS OF PARALYSIS

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ABSTRACT

The second record of paralysis of a mule deer (*Odocoileus hemionus*) by *Dermacentor andersoni* Stiles resulted from infesting a yearling buck with 50 pairs of ticks. A yearling doe previously infested with *D. albipictus* was not paralyzed by the same infestation. Spontaneous infestations of wild and captive mule deer include an engorged nymph of *D. andersoni*. A female of *D. andersoni* weighing 746 mg was removed from a captive moose (*Alces alces*). Infesting a porcupine (*Erethizon dorsatum*) with about 14,800 larvae of *D. andersoni* produced more than 600 pairs of adults in the following year. Fifty pairs of *D. andersoni* applied to the same porcupine yielded a high proportion of engorged females, but the porcupine was not paralyzed.

A coyote (*Canis latrans*) and a skunk (*Mephitis mephitis*) were paralyzed by 50 and 30 pairs of *D. andersoni* respectively. Few or no larvae or nymphs engorged on the skunk or on two laboratory fitches, whereas many engorged on rabbits used as controls. This suggests that Mustelidae may be resistant or unattractive to immature *D. andersoni*. Unconfirmed cases of tick paralysis in foxes have been reported. A new record is included of *D. andersoni* on a marmot (*Marmota monax*).

INTRODUCTION

In British Columbia, some success has attended efforts to estimate populations and infestations of *Dermacentor andersoni* Stiles on small rodents, particularly chipmunks (*Eutamias* spp.) and white footed mice (*Peromyscus* spp.), but methods have not yet been developed of making repeated estimates of infestations on deer, coyotes and porcupines. Practicable methods might involve telemetry, game fences and immobilising drugs. This paper deals with experimental and unintentional infestations of these hosts, and also of moose (*Alces alces*) and skunk (*Mephitis mephitis*) which are less common visitors. Unusual records are included of *D. andersoni* on *Marmota monax* and *M. caligata*.

When engorged ticks are referred to, weights are sometimes given, to provide information on the degree of engorgement and potential egg production (Wilkinson, 1968, Table VII). Weights are not given when the ticks could not be detached for weighing, or when they were obviously not fully engorged. Increasing degrees of engorgement of the female ticks are described by the colours red, tan, and gray, which are familiar to those working with *D. andersoni*.

Mule deer, *Odocoileus hemionus hemionus*

In the first record of paralysis of a mule deer by *D. andersoni* (Wilkinson, 1965), the ticks engorged on a fawn which showed classical paralysis and recovery. Since then there have been other records of *D. andersoni* engorging on wild deer and on a zoo animal, and one trial with laboratory-reared deer. Records from wild deer in the spring tick season are scarce because the hunting season is closed.

Deer snared by Game Department officials, or shot in springtime in the Kamloops area, have yielded many *D. albipictus* but few *D. andersoni*. There were no engorged female *D. andersoni* on these deer even in areas known to be infested with hungry adults. This may still be due to inadequate sampling, as indicated by two documented samples of ticks sent in by Mr. B. Gates, Game Biologist, B.C. Dept. of Recreation and Conservation, taken from deer found near Carpenter Lake in the Lillooet District. Lot 5546 contained 4 male and 13 female *D. andersoni*. The largest females weighed 442,500 and 436 mg. There was one engorged female and one male *D. albipictus*. The deer, a buck about 10 months old, was unable to stand when it was killed about 4 April 1968. A superficial autopsy of the slightly decomposed body a week later showed no injuries to account for the original disability, suggesting that it may have been paralyzed by *D. andersoni*.

Lot 5584, was from an aged female deer in very poor condition, shot near Cedarvale Creek and Carpenter Lake on 11 April 1968. The ticks were distributed as follows:

	<i>D. andersoni</i>			<i>D. albipictus</i>	
	male	female	nymph	male	female
ears				285	116
rest of					
head	4	1 engorged	1		
		2 large tan			
brisket	1			15	16
perianal area				16	11

² "Tick" in this paper refers to *D. andersoni*, except where another specific name is given. The foci of interest in this work are areas associated with cattle-paralysis, mainly in the *Pinus ponderosa* *Agropyron spicatum* zone. (Wilkinson, 1967).

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There was no paralysis. *D. albipictus* contributed most of the tick burden and the large number of males indicated that the burden of female *D. albipictus* had been greater. Not every tick on the deer was collected. This appears to be the first published record of an engorged nymph of *D. andersoni* from a mule deer.

A semi-tame mule deer buck and a doe in a zoo near Kamloops were examined for ticks in April 1967. The deer pen occupied 0.8 ha in sagebrush-ponderosa pine vegetation naturally infested with *D. andersoni*. Two female *D. andersoni* in the large tan stage (178,144 mg) and 3 in the medium tan were removed from the buck on 7 April, and 2 medium and 1 small tan females on 9 April (Lot 5480). One male was found on the doe. It appeared that most of the female ticks on the buck would have engorged normally; no marked skin reactions were seen.

The results of experimental infestations of captive deer are given here in detail because no similar work appears to have been published. A mule deer doe born in 1967 was infested with about 1100 larvae of *D. albipictus* on 19 October 1967, by distributing the larvae over the head, ears, back and legs. The larvae had hatched at room temperatures and were placed in an outdoor enclosure on 3 October. The larvae used for infesting had ascended to the grass tips, indicating that their summer diapause was ended (Wilkinson, 1967). A mule deer buck, also born in 1967, was left uninfested, separated from the doe by a fence from the day of infestation. During the course of the experiment the buck was accidentally together with the doe for a few hours, but the only *D. albipictus* seen on it was one nymph 1.5 mm long. Both animals were examined at about weekly intervals. Progress of the infestation on the doe was as follows; 23 October. Larvae attached but undistended; on the back, but not the ears. 1 November. Larvae distended, creamy white. One nymph on anus. 8 November. Light brown nymphs 1.5-2 mm long, undistended, mainly on neck, withers and rump.

8 November-17 January. Nymphs remained undistended. Weather cold, snow melted slowly in hair on 21 December. On 17 January, estimate of 30+ nymphs on withers, 6+ on neck, 2+ on rump, 0 on perianal region.

23 January. One nymph 5 mm long on edge of white hair near tail. One 2 mm long; remainder 1.5 mm long. Coat starting to shed.

6 February. Rump, near white patch, 1 male. Elsewhere 5 nymphs 3-5 mm long; remainder 2 mm or less.

20 February. Rump 1 male, withers and neck 2 females; 1 flat female, many nymphs 1.5 to 5 mm

long on rump, withers, neck. Left ear, 2 nymphs, 2 mm long.

18 March. Ears, 2 females, 2 nymphs; withers 1 female, 3 nymphs; anus 2 females, 1 male.

21 March. One $\frac{3}{4}$ -fed female near anus.

25 March. Three half-engorged females on brisket, one removed.

27 March. Final removal-2 red females, 1 male. Probably about 10 engorged females dropped off previously. The doe, estimated to weigh 36 kg, was immobilised with 2.6 mg succinyl chloride given intramuscularly in 1.3 cc distilled water, for this check.

To infest the deer with *D. andersoni*, the ticks were shaken on to the back. They walked on the outside of the guard hairs for several minutes, before burrowing towards the skin. The deer were examined at least once daily from three days after infestation, while they were being fed and petted and they were fully immobilised for the final close examination. Records were kept of the susceptibility of the deer to paralysis by ticks, the percentage of female ticks engorging within a time limit, and the places of attachment on the deer (Table I).

It was concluded that a light infestation with *D. albipictus* starting with 1000 larvae, which produced about 100 nymphs and finally some tens of adults, did not prevent engorgement of *D. andersoni* females on the doe. Whether *D. albipictus* provides protection against paralysis from *D. andersoni* is unknown; an answer would necessitate repetitions of the trial, distributed appropriately between sexes and age groups of deer. The paralysis of the buck was the first record of paralysis of a yearling mule deer.

In an attempt to paralyze both animals, the deer were reinfested with 100 pairs of *D. andersoni* each on 13 May 1968, by shaking the ticks into loose cloth collars round their necks. A check four days later revealed only one unattached male on the buck and observations ceased. The deer were together, and such factors as mutual grooming, summer pelage, or the mode of infestation, may have contributed to the failure of the ticks to engorge. It is possible that immune reactions were involved.

Moose

In Canada, the moose, *Alces alces andersoni*, was very rare in areas infested with *D. andersoni* before 1920 (Cowan and Guiguet, 1965), and the race *A. a. shirasi* penetrated into the range of *D. andersoni* only in the extreme south of the Canadian Rockies. The winter range of *A. a. andersoni* has now expanded southwards to include numerous tick foci in southern British Columbia. Moose must pick up many ticks even though they are less exposed to ticks than mule deer, because moose tend to leave the tick foci for higher altitudes earlier in the year than mule deer,

TABLE I

Development of female *D. andersoni* on a buck and doe mule deer, and symptoms of paralysis of the buck. Each was infested with 50 male and 50 female ticks (collected 6-8.iii.68 and stored at 5 C) on 18.iii.68. The doe had a concurrent infestation with *D. albipictus* (see text).

Buck			Doe	
Date	No. & Stage of ticks	Location of ticks. (Symptoms in brackets)	No. & Stage of ticks	Location of ticks
March 1968				
21	10 red and small tan	Back of head and between eyes	2 red 1 small tan	Head Neck
22	9 medium tan 5 medium tan	Head Neck	4 1 1	Between ears Neck Withers
23	13 medium tan 2 medium tan	Face and back of head Neck	8 small to large tan 3	Back of head Back of neck
24	14 medium-large tan 4 medium tan	Head Neck	7 medium large tan 3+ small to large tan (2 large tans removed)	Back of head Withers and neck
25	2 grey ticks removed (480,650 mg)	Not recorded (Rear legs unsteady)	2 grey ticks removed (722,512 mg) 3 grey removed (474, 500,575)	Head Withers
26	10 grey ticks removed	Head and neck (Fell easily, difficulty in getting up)	2 grey of which 1 removed 3 tan	Neck Head
27	7 grey ticks removed 4-5 tans	Head Face (Slight paralysis)	All ticks removed 7 medium tan 1 large tan	Not recorded
28	Remaining ticks removed 4 grey 6 tan	Not recorded (Recovered from paralysis)		
Total female ticks removed from buck 23 grey (engorged) and 6 tan			Total female ticks removed from doe 6 grey and 10 tan	

often before the season of adult tick activity. We see fresh moose droppings and occasionally moose while collecting ticks, but we are reluctant to shoot them in spring to obtain host records. Moose are not recorded as hosts of *D. andersoni* by Bishopp and Trembley (1945) or Cooley (1938). An opportunity occurred to examine two moose confined with the mule deer in the zoo mentioned above. On 7 April 1967 three female *D. andersoni*, one engorged weighing 746 mg, one partly fed, and one unfed, were removed from

the head and neck of one of the moose.

Coyote, Canis latrans

Coyote faeces and coyotes are commonly seen on tick foci in the Kamloops area; the coyotes are probably attracted by the presence of rodents. No case of tick paralysis of a coyote has been recorded in nature and there were no records at Kamloops of *D. andersoni* on coyotes, but there were two records of *D. albipictus*, one of *Ixodes rugosus* and one of *Ixodes sculpus*. Bishopp and Trembley (1945) list

one lot of 15 male and 16 female ticks from a coyote, the females ranging from unfed to partly fed. This may have been the same coyote listed by Henshaw and Birdseye (1911).

A female coyote pup of the year was obtained on 25 May 1968 and infested with 50 male and 50 female *D. andersoni* on 26 August 1968. The coyote was caged over a water tray and 25 pairs of ticks were placed on top of the head, the remainder on the neck and withers. By 30 August, 13 or more females with males, were attached on the head, and other females were attached as follows: base of left ear, 1; base of right ear, 2; withers, 1; neck, 1. A slight disability was noted in the coyote on the evening of the 30th. On 1 September, the rear legs collapsed when the coyote was taken out of the cage, and its movements were unco-ordinated. On 2 September,

the inco-ordination was greater and the front legs were weak, with lack of tone in the paws (Fig. 1). All the ticks seen were removed, mostly from the head near the point of release. They consisted of 1 fully engorged female (527 mg), 4 large, 10 medium and 14 small tans plus 20 males, mostly fed. Two large tan females and one male were removed on 4 September. Three males and 5 females, all unfed, were taken from the water tray. The coyote had partly recovered by the 3rd, and was completely recovered on the 4th, when it weighed 4.4 kg. It was thus demonstrated that *D. andersoni* could engorge on and paralyze a coyote. Probably 30 out of the 50 would have engorged had the animal not become paralyzed. This is the first record of tick paralysis in a coyote.



Fig. 1. Coyote paralyzed by *D. andersoni* on 2 September 1968. Animal recovered after the ticks were removed.

Porcupine, Erethizon dorsatum nigrescens and E. d. epixanthium

Little has been published on the host-potential of this interesting rodent. Jellison (1933) reported that it is an important host of all parasitic stages of *D. andersoni*. Bishopp and Trembley (1945) record only adult ticks. The Erethizontidae evolved in South America and travelled north in the late Pliocene (Dawson, 1967) whereas the ancestors of many of the present hosts of North American ticks crossed from Eurasia, via Beringia. The porcupine's ability to sustain heavy infestations of all stages indicates a long adaptation to *D. andersoni*.

A porcupine captured alive near Stump Lake on

5 May 1967 was caged over a water tray. It yielded ticks as follows until it died on 9 May: 5 May; females weighing 948 and 710 mg. 7 May; females weighing 900, 870, 768, 615, and 503 mg. 9 May (after death); females weighing 628, 617, 550 and 842 mg, 2 engorging nymphs and 23 males. 10 May; 1 engorged nymph and 1 *Ixodes* larva. Most of the females were on the underside (cf. Wilkinson & Lawson, 1965). Two porcupines, probably of subspecies *epixanthium*, were obtained at Onefour, Alberta on 29 April 1964. One, which was shot, carried 7 male and 4 female ticks, the other, which was found dead, carried 10 males and 5 females.

Figures for porcupines abundance on tick foci

cannot yet be given, but faeces and lairs, and signs of feeding by porcupines on pines, occur regularly in tick foci, especially in the ponderosa pine-wheatgrass zone. The porcupines themselves are not often seen, and their numbers may be limited by the availability of suitable refuges or some unknown factor. An indication of the potential yield of ticks from a porcupine was obtained by infesting a caged porcupine outdoors on 26 June 1967 with larvae from 933 mg of eggs. The eggs and larvae had been kept at room temperatures. Assuming 16.6 eggs/mg and 90% hatch, this represents about 14,800 larvae. The following year 740 male and 622 female ticks were collected from the cage between 26 February and 29 May, when activity ceased. A white mouse enclosed in metal mesh attracted one nymph on 23 April 1968 and another flat nymph was seen. The porcupine was returned to the cage from its winter quarters on 3 May and remained until 2 July 1968 so that any nymphs present could feed. Only two male ticks appeared in 1969.

On 2 July 1968, 50 male and 50 female ticks from the spring collection mentioned above were placed on the porcupine, which was caged over water. Forty-five fed and partly fed females were recovered, averaging about 502 mg. These should yield an average of 317 mg of eggs each (Wilkinson, 1968, Table VII). If all 622 females had fed on the porcupine, the multiplication factor in one year calculated from egg weights, would have been about 199. This figure would not be reached in nature because many of the hungry ticks would die before engorging and ovipositing, but it illustrates the importance of porcupines in maintaining tick populations without the necessity for other hosts. The porcupine weighed 8.6 kg on 16 October 1967 and 14.2 kg on 3 May 1968.

Mustelidae

Weasels probably occur regularly on tick foci. At Stump Lake two weasels were caught in Sherman traps. The weasel caught on 20 July 1967 was identified provisionally as *Mustela erminea* and that on 7 August 1968 as *Mustela frenata nevadensis*. Two nymphs of *Ixodes kingi* were found on the first and 1 female and 30 nymphs of *I. kingi* on the second, with an unattached nymph of *D. andersoni*. Considering the extensive travels of weasels in rodent haunts, a heavier infestation with *D. andersoni* would have been expected.

Striped skunks (*Mephitis mephitis*) are probably infrequent visitors to foci of *D. andersoni*. I have not seen them during many hours of flagging for ticks and trapping on tick foci. Cowan and Guiguet (1965) state that "open fields, marshes and streamside thickets mixed with dense cover are the favoured haunts of this animal in British Columbia",

and this does not describe tick foci. The following records of skunks killed on roads show that they carried only *Ixodes* ticks, even though they were within the general distribution of and season for *D. andersoni*: — Herbert, Saskatchewan 10.v.66-1 nymph of *I. kingi*; Kamloops, B.C., 17.vii.68, 1 nymph of *I. marmotae*.

In trials with a tame, obese, castrated male skunk, surgically deprived of stink glands, we found that adult ticks fed on the animal more slowly than on favoured hosts, and larvae did not attach. Thirty male and 30 female *D. andersoni* were liberated on the back of the animal on 23 May 1968. The cage was suspended over water. The female ticks engorged slowly and were only half or less engorged by 1 June. They weighed 228, 144, 128, 135, 110, 21, 28, 20 mg. The ticks were removed because the skunk was showing lack of co-ordination and weakness of the rear legs. Next day the skunk had recovered. This is the first record we know of tick paralysis in a skunk. The skunk was placed in an outdoor cage, in a site known to be suitable for development of *D. andersoni*, and was infested with about 6000 larvae on 10 September 1968. No fed larvae were seen on the skunk or in the water tray during the next three days.

To check the apparent unsuitability of Mustelidae for immature stages of *D. andersoni*, a trial was set up comparing the same skunk and two laboratory fitches (*Mustela putorius*?) with laboratory rabbits. About 5000 larvae each were applied to the skunk, both of the fitches and two rabbits, caged individually. All the cages were kept in bags. On 27 September the rabbits' bags yielded 205 and 34 larvae, the skunk and fitches' bags nothing. Next day the rabbits' bags yielded 195 and 260 larvae, the skunk's bag one well-fed larva and the fitches' nothing. No further feeding larvae were seen on the fitches or the skunk on 30 September, so observations stopped. The rabbits were kept in the bagged cages until 4 October when six and no fed larvae were recovered.

The only other member of the Mustelidae that is common near tick foci in this province is the badger, *Taxidea taxus taxus*. Marten, fisher, mink, wolverine and spotted skunk would rarely encounter *D. andersoni*. In the Kamloops records, one of the two records of ticks from badgers is *D. andersoni*. This is an unfed nymph, still in the collection in damaged condition, taken on 12 July 1934, on range land northeast of Kamloops. Bishopp and Trembley (1945) record only one tick, a male, from badger. This is quite probably the same dead male tick collected by Henshaw and Birdseye (1911). Thus there is no evidence as yet that *D. andersoni* feeds successfully on badgers.

Marmota monax and *caligata*

It seems appropriate to present here a hitherto unpublished host record for *D. andersoni*. *Marmota monax petrensis* occurs in part of the range of *D. andersoni* in British Columbia (Cowan and Guiguet, 1965) but is comparatively rare. It is doubtful whether it has been checked for infestation in the U.S.A. where it is rare in the range of *D. andersoni*. One *M. monax* collected on 21 May 1939 yielded a nymph and another two engorged female ticks of *D. andersoni*. Both marmots came from a collection of four made by the late E. R. Buckell at Wigwam Mine (Lat. 50° 50', Long. 118° 00'), at about 2500 ft. altitude. The same site yielded another unusual record on 10 June 1939, when one engorged and four or more flat nymphs of *D. andersoni* were secured from *Marmota caligata* by J. D. Gregson. *M. caligata* is usually associated with high altitudes above timberline. The ticks from *M. caligata* are preserved on a slide; those from the *M. monax* are evidently lost.

Fox, Vulpes fulva

Tick-infested paralyzed foxes were reported from Dog Creek in April 1966, by a Mrs. M. Elgood who sent unfed *D. andersoni* adults emerging from soil washed down in the spring. A picture of a fox which

had been kept captive after recovery from this "paralysis", was sent in by Mr. Lesowski, Conservation Officer, Department of Recreation and Conservation at Williams Lake, but a definite diagnosis of tick paralysis was not made. Marsh (1929) reported tick paralysis of a blue fox by a wood tick in Montana.

DISCUSSION

The present evidence on susceptibility of deer shows that *D. andersoni* will engorge on mule deer in nature, but there is also a suggestion that the infestation on many deer is not so heavy as would be expected from the number of ticks encountered (cf. low infestations of deer with *D. variabilis* in Nova Scotia (Dodds, Martell, & Yescott, 1968).

Further experiments will be necessary to test whether deer can be paralyzed, and whether prior infestation with *D. albipictus* protects deer from paralysis by *D. andersoni*.

This paper thus adds captive mule deer, coyote and skunk to the list of animals susceptible to paralysis (Gregson 1958). Reports on mule deer and foxes suggest that they may have been suffering from tick paralysis in nature. The apparent repellence or resistance of Mustelidae to the immature stages of *D. andersoni* should be tested by further experiments.

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ANNOTATED LIST OF FOREST INSECTS OF BRITISH COLUMBIA, PART XIV, *POLYGONIA*, *NYMPHALIS* AND *LIMENITIS* (NYMPHALIDAE)

B. A. SUGDEN¹

Many members of the family Nymphalidae are found in British Columbia but only a few species, regarded as economically unimportant, feed on the foliage of forest trees. Small localized outbreaks of some species have been recorded in British Columbia but all were of short duration. The caterpillars are usually spiny, pale to dark and obscurely or strikingly marked. The chrysalids are angularly tuberculate, naked, dull or marked with gold or silver, and are suspended by the cremaster in sheltered sites. The number of collections per host is shown only when fewer than five.

Polygonia faunus Edw. - *Betula* spp. (4 records), *Salix* spp. (3). Throughout British Columbia, including Vancouver Island, uncommon on forest trees. LARVA: 1½ inches; head bilobed, dull black marked with white, pale chalazae and setae, prominent black scoli armed with spines on vertex of each lobe; body pale brown with irregular markings of yellow, dull white and medium brown, dull white dorsal stripes; TI with a band of small tubercles extending to sides; pale addorsal and spiracular scoli with black-tipped spines on TII-III; middorsal, addorsal, supraspiracular and subspiracular scoli on A1-7 are pale yellowish white, except lower half of supraspiracular scoli which are pale brown, all with pale black-tipped spines; A8 similar but with two supraspiracular scoli, A9 with one pair of supraspiracular scoli, black-tipped spines and dark brown anal shield; venter paler than dorsum with sparse but prominent setae; thoracic legs and prolegs marked dark brown.

Polygonia zephyrus Edw. - *Salix* sp. (1 record), *Alnus* sp. (2) and the shrubs *Menziesia ferruginea* Smith, *Ribes* spp. Throughout British Columbia, including Vancouver Island, uncommon on forest trees. LARVA: 1¾ inches; head moderately bilobed, shiny black with white markings and white chalazae and setae, black scoli with black spines on vertex of each lobe; body with dorsum of TI-III and AI and 2 dull yellowish orange; A3-9 dull white lightly marked brown, dark brown and black; pale yellow addorsal scoli TI-III, pale middorsal scoli A1-8; all scoli with pale black-tipped spines, anal shield black; lateral dull white, heavily marked pale and dark brown, irregular dull yellow supra- and subspiracular lines, supraspiracular scoli on TII-III and A9, supra- and subspiracular scoli A1-A8, all with

pale setae; thoracic legs and anal prolegs marked black; venter dull orange finely marked pale brown, darker than dorsum.

Polygonia gracilis C. & R. - *Salix* sp. (2 records). Clemina, B.C. LARVA: similar to *P. zephyrus* except that in the dark phase, pale portions are washed with pale buff and brown.

Nymphalis j-album Bdv. & LeC. - *Betula* sp., *Salix* spp. Southern interior and lower Fraser Valley of British Columbia; uncommon on forest trees. LARVA: 1½ inches; head dull black, moderately bilobed with prominent black spined scoli on vertex of each lobe and setae arising from white chalazae; body pale yellow profusely marked medium and dark brown; yellow middorsal line on TI, irregular pale yellow addorsal lines TII-A8; addorsal and subdorsal pale yellow chalazae with dark brown or black setae on TI, middorsal and subdorsal black spined scoli TII-A8, subdorsal black spined scoli on A9; black spined spiracular scoli TII-III, black supra- and pale yellow subspiracular scoli A1-8, pale yellow subspiracular line; venter pale, sparsely marked pale brown with white setae arising from pale chalazae; thoracic legs and prolegs dull yellow marked pale brown.

Nymphalis antiopa Linn. - *Salix* spp. *Populus* spp. Throughout British Columbia, including Vancouver Island. Common, occasionally causing severe defoliation of individual trees. LARVA: 1½ inches; head dull black with white setae on black chalazae; body black banded with rows of small white spots; A1-7 with one large yellowish-orange to red middorsal spot on each segment, broken middorsal line TII-A8, black setaceous middorsal scoli A4-8 and black setaceous addorsal scoli TII-A9; black setaceous spiracular scoli TII-III, black setaceous supra- and subspiracular scoli A1-8; venter flecked with small white spots, black midventral line; thoracic legs and anal prolegs black, abdominal prolegs yellowish-orange to dull red.

Limenitis arthemis Dru. - *Populus tremuloides* Michx. *Salix* spp. Central and northern British Columbia; uncommon on forest trees. LARVA: 1¾ inches; head pale brown, bilobed with one pair modified scoli on vertex of each lobe and short pale setae on prominent chalazae; body dark yellowish brown or olive-green; dorsum of TI-II and A4-6 pale mauve or white extending ventrad of A5, occasionally suffused with pale pink; remainder sparsely marked dark brown and black; two

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prominent subdorsal scoli on TII, small short subdorsal scoli on TI and III, A1-3 and 7-9, scoli much reduced or lacking A4-6; pale buff subspiracular line A1-9 extending down sides of anal prolegs; venter with numerous pale setae on dull white chalazae, thoracic legs black, dull white chalazae and pale setae on prolegs.

Limnitis lorquini burrisonii Mayn. - *Populus trichocarpa* Torr. and Gray, *Populus tremuloides* Michx. *Salix* spp. Southern British Columbia; may hybridize with *L. arthemis* at about 51° latitude; uncommon on forest trees. LARVA: 1¾ inches, similar to *L. arthemis*, head pale lilac to pale mauve-

tan, bilobed with one pair modified scoli on vertex of each lobe, short pale setae on prominent chalazae; body dark brown-purple to gray-mauve; dorsum of TI-II and A4-6 white, washed with pale mauve extending ventrad on A5; remainder of dorsum sparsely marked brown and black with two prominent subdorsal scoli on TII, small subdorsal scoli on TI and III, A1-3 and 7-9; scoli much reduced or lacking A4-6; mauve-white subspiracular line A1-9 extending down sides of anal prolegs; venter with numerous pale setae on dull white chalazae; thoracic legs black; dull white chalazae and pale setae on prolegs.

INSECTS AND INSECTICIDES

By R. C. Reay

Oliver & Boyd Ltd., Edinburgh

1969. Pp. 152. \$1.50

A sharp little controversy boiled up recently in *Science* about books on scientific writing and on scientific writing itself. This is all to the good; we need to be reminded of our shortcomings. Most of us are guilty of writing that is inflated, or wordy, or complicated, or just dull, or all four. Part of the trouble is that we tend to think in special scientific terms and since we are fearful of being misinterpreted we write in the same way, playing it safe by using clichés. In papers which will be read only by people on the same wavelength as ourselves, there is little harm done, but in a book before the general public which is expected to sell, some sparkle and color are needed.

Insects and Insecticides is a case in point. The subject is topical but the book will never be a best seller. The format, the printing, the type, the price, the paper, and most of the illustrations are good. I saw only two small typesetting errors, the arrangement and coverage are excellent and the scientific content is hard to fault. Many people will buy it but fewer will read it, because the writing has too high a content of pedagogue. Or perhaps it is overscholarly. On p. 7 is an example: "From the foregoing account it will be apparent that insects are well provided with the means to seek out and recognize a source of nourishment." In other words, insects are evidently well equipped to find and recognize food? On p. 5 the "odours of putrefaction" and the "smell of sweat" somehow got into the same

sentence. The author is never obscure but he clearly is capable of much sprightlier prose than the text indicates. The introduction, written in the first person, is proof. It ends with a graceful tribute for her help to his wife, who "... suffered the whole process willingly, kept the children at bay, and who helped with the typing . . ."

This is carping criticism because it is such a cool and well-conceived book; students in entomology and especially those in allied disciplines will find it an excellent and comprehensive summary. Surely students rather than laymen are the audience in mind when, without apology or explanation, the author speaks of exopterygote nymphs (p. 2), cuticular sensillae, monovalent salts (p. 4), plants containing isothiocyanates, oviposition loci, the glycosides phaseolunatin and lotaustrian, beta-gamma-hexanol and alpha-beta-hexanal all within the first five pages. There is a fairly technical section (p. 27-33) on the role of inorganic ions in digestion and nutrition. The author means to sort the men from the boys early.

There are three major sections: What is an insect pest? (33p.); Which insects are pests? (33 p.); How are insect pests controlled? (79 p.). The index of 5½ pages includes 225 proper names of species or genera, and the names of the chemicals discussed. He shows 73 structural formulae in the text including some chemosterilants, botanicals, synergists, attractants, repellents, and two anti-feeding agents. A few references are made in the text to author and year only but these are not listed elsewhere.

Some of the more volatile ecologists would do very well to invest in this unemotional and factual little paperback.

AN ABERRATION IN THE DIGESTIVE SYSTEM OF *SCHISTOCERCA GREGARIA* (FORSK.)

WILLIAM F. DEAN¹

In a stock colony of the desert locust, *Schistocerca gregaria* (Forsk.) one newly-moulted fifth-instar nymph was seen to have an orifice on the middle of the vertex of the head. The insect seemed unable to hop and had difficulty in walking and eating. Its mandibles moved slowly and inefficiently and unconsumed food often remained between them.

Soon after its first meal the locust started to pass feces through the orifice in its head (Fig. 1) but no feces passed through the anus. Occasionally the hindlegs moved, apparently spontaneously, but the grasping ability of the hind tarsi was temporarily lost. After three days, no more feces passed through the opening in the head but very thin, elongated feces began to pass through the anus. Between the fourth and fifth day the leg tremors disappeared, the insect regained the ability to hop, and eating became

normal. By the tenth day normal feces were passed through the anus. On the eleventh day the locust moulted to an adult, normal in all respects apart from a light spot on the head where the opening had been in the 5th instar.

The feces eliminated through the opening in the head appeared to have been at least partially digested (Fig. 1). This suggests a temporary dual aberration consisting of an anal obstruction and a diverticulum of the digestive tract from the midgut or hindgut to the opening in the head. The adult locust lived for approximately two weeks, but unfortunately died and was eaten by other locusts in the colony before dissections could be made.

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Fig. 1 Fifth instar nymph of *S. gregaria* passing feces through dorsal opening in the head.

A WORLD LIST OF PARASITES OF COCCINELLIDAE¹J. V. RICHESON²

ABSTRACT

The parasitic organisms attacking Coccinellidae of the world are presented in two lists: parasites of a given host, and hosts of a known parasite. Parasites listed include: 9 fungi, 1 bacterium, 8 protozoans, 9 nematodes, 2 mites, and 83 insects. Forty-three genera and 125 species of coccinellid hosts are included. Two hundred and three references are cited.

INTRODUCTION

The current interest in biological control or integrated control programs against insect pests requires a full understanding of the organisms being used. Coccinellids, a widely used group of predators, are attacked by various parasitic or pathogenic organisms. These organisms may reduce the effectiveness of predators or even prevent their establishment. The following lists are compiled from published reports of parasitic organisms on all stages of coccinellids of the world.

The first list contains coccinellid species listed alphabetically with their parasites. The numbers refer to literature citations. The second list contains the parasites found attacking coccinellids. The parasites are listed phylogenetically and the genera alphabetically. An asterisk against names of parasites in second list indicates synonymy. A list of synonyms is given. The parasites are coded as follows: F-Fungi, B-Bacteria, G-Gregarinidae, M-Microsporidia, N-Nematoda, A-Acarina, DP-Diptera Phoridae, DT-Diptera Tachinidae, HB-Hymenoptera Braconidae, HC-Hymenoptera Ceraphronidae, HCH-Hymenoptera Chalcididae, HEN-Hymenoptera Encyrtidae, HEU-Hymenoptera Eulophidae, HEP-Hymenoptera Eupelmidae, HI-Hymenoptera Ichneumonidae, HP-Hymenoptera Proctotrupidae, HPT-Hymenoptera Pteromalidae.

HOST LIST

COCCINELLIDAE

Anisotylus sp. (HEN) 70
A. similis texanus (HEN) 143, 185
Clistomorpha triangulifera (DT) 70
Degeeria collaris (DT) 66, 70
Doryphorophaga doryphorae (DT) 70
Exoristoides slossanae (DT) 70
Homalotylus sp. (HEN) 8, 140
H. albivarsus (HEN) 135, 143, 185
H. flaminus (HEN) 3, 151, 152, 187

H. terminalis terminalis (HEN) 76, 143, 170, 200
Lydinolydella brucki (DT) 70
L. metallica (DT) 70
Ooencyrtus johnsoni (HEN) 73, 135, 143
Perilitus coccinellae (HB) 14, 27, 55, 70, 142, 187
Phalacrotophora berolinensis (DP) 70
Ph. fasciata (DP) 117
Ph. nedae (DP) 70
Nemorilla maculosa (DT) 70
Sarcophaga latisternus (DT) 70
S. rapax (DT) 70
S. reinhardi (DT) 70
Stomatomyia edwardsi (DT) 70
Tetrastichus coccinellae (HEU) 117
T. minutus (HEU) 143, 196

Adalia sp.

Phalacrotophora fasciata (DP) 8, 70
Tetrastichus sp. (HEU) 7

A. bipunctata L.

Beauveria bassiana (F) 68, 136
Homalotylus terminalis californicus (HEN) 48, 135, 143, 185
Parasitylenchus coccinellae (N) 83
Perilitus coccinellae (HB) 7, 20, 30, 171, 187, 189
P. stuardoi (HB) 29
Phalacrotophora fasciata (DP) 8, 74, 125, 129, 154, 187
Tetrastichus coccinellae (HEU) 74, 87
T. epilachnae (HEU) 50, 187
T. minutus (HEU) 95, 143, 186
Unidentified Diptera (D) 154
Unidentified Tachinidae (D) 74

A. decempunctata L.

Degeeria luctosa (DT) 190
Perilitus coccinellae (HB) 189

A. deficiens Muls.

Perilitus stuardoi (HB) 29

A. flavomaculata DeGeer

Homalotylus sp. (HE) 4, 187
Perilitus sp. (HB) 133, 187

A. frigida Schneider

Perilitus coccinellae (HB) 48, 171

A. undecimpunctata L.

Clistomorpha triangulifera (DT) 9
Perilitus coccinellae (HB) 189

¹ Part of this work was completed at the University of Missouri, supported by the USDA, and the National Research Council of Canada.

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Adonia* sp.Homalotylus* sp. (HEN) 8*Perilitus coccinellae* (HB) 141*Phalacrotophora fasciata* (DP) 8, 70***A. undecimnotata* Schneider***Beauveria bassiana* (F) 74, 87*Mermis* sp. (N) 74, 87, 88*Perilitus coccinellae* (HB) 74, 87*Phalacrotophora fasciata* (DP) 8, 74

Unidentified Tachinidae (DT) 74

A. variegata* (Goeze)Gregarina* sp. (G) 87*Homalotylus flaminus* (HEN) 72, 87, 187, 199*Mermis* sp. (N) 74, 87, 88*Pachyneuron* sp. (HPT) 199*Parasitylenchus coccinellae* (N) 88*Perilitus coccinellae* (HB) 74, 87, 118, 141, 171, 187, 189*Phalacrotophora* sp. (DP) 87*Ph. fasciata* (DP) 3, 74, 187*Tetrastichus* sp. (HEU) 187, 199

Unidentified Tachinidae (DT) 74

Anatis ocellata* L.Phalacrotophora fasciata* (DP) 125, 187***A. quinquedecimpunctata* DeGeer***Homalotylus terminalis terminalis* (HEN) 143, 185, 187*Perilitus coccinellae* (HB) 30, 187***A. rathvoni* LeConte***Nosema hippodamiae* (M) 115***Aphidecta oblitterata* L.***Hexameris* sp. (N) 36*Phalacrotophora berolinensis* (DP) 36***Azya luteipes* Mulsant = *A. orbigera****Metastenus townsendi* (HPT) 63, 187***Calvia quatuordecimpunctata* L.***Phalacrotophora fasciata* (DP) 117, 125, 187*Tetrastichus coccinellae* (HEU) 117***Chilocorus* sp.***Homalotylus* sp. (HEN) 8, 70*H. flaminus* (HEN) 53*Phalacrotophora fasciata* (DP) 8, 70*Tetrastichus* sp. (HEU) 7***C. bijugus* Mulsant***Tetrastichus neglectus* (HEU) 40, 41***C. bipustulatus* L.***Achrysophagus aegyptiacus* (HEN) 158*Anastatus disparis* (HEP) 179, 187*Aphanogmus* sp. (HC) 187*Eupelmus* sp. (HEP) 187*Hesperomyces virescens* (F) 98, 203*Homalotylus latiscapus* (HEN) 187*Homalotylus* sp. (HEN) 140*H. flaminus* (HEN) 13, 72, 121, 158, 160, 167, 169, 177, 187, 198, 202*Lygocerus* sp. (HP) 179*Pachyneuron chilocori* (HPT) 39, 202*Phalacrotophora fasciata* (DP) 129, 187*Pseudocatalaccus* sp. (HPT) 175*Tetrastichus coccinellae* (HEU) 15, 41, 160*T. epilachnae* (HEU) 17, 101, 121, 169, 187, 195*T. neglectus* (HEU) 39, 41, 126, 179*T. sempronius* (HEU) 40, 41

Unidentified Laboulbeniaceae (F) 72

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PARASITES ATTACKING COCCINELLIDS

FUNGI

- Beauveria bassiana* Vuillman — *Adalia bipunctata*,
Adonia undecimnotata, *Coccinella quinquepunctata*, *C. septempunctata*, *C. trifasciata*, *Epilachna varivestis*, *Harmonia quadripunctata*.
B. tenella (Del.) Siemasko — *Epilachna vigintioctopunctata*
Cladosporium sp. — *Cycloneda sanguinea*
Hesperomyces virescens Thaxter — *Chilocorus bipustulatus*
Laboulbenia sp. — *Coccinella undecimpunctata*
Laboulbeniaceae — *Chilocorus bipustulatus*
Metarrhizium anisopliae (Metchnikoff) —
Epilachna vigintioctopunctata
Myrothecium roridum Tode — *Epilachna varivestis*
Phyllactinia suffulta (Reb.) Sacc. — *Halyzia duodecimguttata*, *H. sedecimguttata*, *H. vigintiduopunctata*
Unidentified Fungi — *Olla abdominalis*

BACTERIA

- Bacterial or Viral — *Stethorus punctillum*
Unidentified Bacteria — *Cycloneda sanguinea*,
Hippodamia convergens

Protozoa

- Gregarinidae
Gregarina sp. — *Adonia variegata*, *Coccinella septempunctata*, *Harmonia conglobata*, *H. quatuordecimpunctata*, *Pullus impexus*
G. coccinellae Lipa — *Coccinella quinquepunctata*,
C. septempunctata, *Myrrha octodecimguttata*
Unidentified Gregarinidae — *Hippodamia convergens*, *Coccinella undecimpunctata*
Microsporidia
Nosema coccinellae Lipa — *Coccinella septempunctata*, *Hippodamia tredecimpunctata*,
Myrrha octodecimguttata
N. hippodamiae Lipa — *Anatis rathvoni*, *Hippodamia convergens*, *Olla abdominalis*

N. tracheophila Cole and Briggs — *Coccinella septempunctata*
Rickettsia stethorae Hall — *Stethorus* sp., *S. gilvifrons*, *S. punctum*, *S. punctillum*
Unidentified Microsporidia — *Hippodamia convergens*

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Agameris decaudata Christie — *Coleomegilla maculata*
Hexameris sp. — *Aphidecta oblitterata*
Mermis sp. — *Adonia undecimnotata*, *A. variegata*, *Coccinella septempunctata*, *Harmonia quatuordecimpunctata*
M. coccinellae Dies. — *Coccinella septempunctata*
M. nigrescens Duj. — *Coccinella septempunctata*
Nematodeum scymni glacialis Dies. — *Scymnus glacialis*
Parasitylenchoides sp. — *Harmonia conglobata*, *H. quatuordecimpunctata*
Parasitylenchus coccinellae Iperti and Waerebeke — *Adalia bipunctata*, *Adonia variegata*, *Harmonia conglobata*, *H. quadripunctata*, *H. quatuordecimpunctata*
Unidentified Mermithidae — *Pullus impexus*
Unidentified Nematode — *Coccinella trifasciata*, *Coleomegilla maculata*

ACARINA

Tetrapolipus hippodamiae McDaniel and Morrill — *Hippodamia convergens*
Typhlodromus fallaxis (Garman) — *Stethorus punctillum*
Unidentified Acarina — *Chilocorus bipustulatus*

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P. berlinensis Schmitz — *Aphidecta oblitterata*, *Coccinellidae*
P. fasciata Fall. — *Adalia* sp., *A. bipunctata*, *Adonia* sp., *A. undecimnotata*, *A. variegata*, *Anatis ocellata*, *Calvia quatuordecimguttata*, *Chilocorus* sp., *C. bipustulatus*, *Coccinella* sp., *C. septempunctata*, *C. undecimpunctata*, *Coccinellidae*, *Cydonia* sp., *Harmonia quatuordecimpunctata*, *Hippodamia* sp., *Neomysia* sp., *N. oblongoguttata*, *Semiadalia* sp., *S. undecimnotata novempunctata*, *Thea* sp., *T. vigintiduopunctata*, *Vibidia* sp., *V. duodecimguttata*
P. nedae Schmitz — *Coccinellidae*
Tachinidae
Clistomorpha triangulifera (Loew) — *Adalia undecimpunctata*, *Coccinella trifasciata*, *Coc-*

cinellidae, *Coleomegilla* sp., *Coleomegilla maculata*, *Epilachna* sp., *E. varivestis*
Degeeria collaris Fall. — *Coccinellidae*
D. luctosa Meigan — *Adalia decimpunctata*, *Semiadalia undecimnotata*
Exoristoides slossonae Coq. — *Coccinellidae*, *Epilachna varivestis*
Doryphorophaga doryphorae Ril. — *Coccinellidae*
Lydinolydella brucki Blanch. — *Coccinellidae*
L. metallica Townsend — *Coccinellidae*, *Epilachna* sp., *E. eusema*, *E. marginella*
Nemorilla maculosa Mg. — *Coccinellidae*, *Epilachna varivestis*
Paradoxodes epilachnae Aldrich — *Epilachna varivestis*, *E. defecta*, *E. philippinensis*
Phorocera doryphorae Riley — *Epilachna varivestis*
P. claripennis Macquart — *Epilachna varivestis*
Sarcophaga latisternus Park. — *Coccinellidae*, *Epilachna varivestis*
S. rapax Walk. — *Coccinellidae*, *Epilachna varivestis*
S. reinhardi Hul. — *Coccinellidae*, *Epilachna varivestis*
Stomatoyia edwardsi Will. — *Coccinellidae*
Unidentified Tachinidae — *Adalia undecimpunctata*, *Adonia undecimnotata*, *A. variegata*, *Epilachna varivestis*, *Harmonia conglobata*, *H. quatuordecimpunctata*
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Hymenoptera — Braconidae
Centistes scymni Ferriere — *Pullus impexus*
Perilitus sp. — *Adalia flavomaculata*, *Chilomenes lunata*, *Exochomus nigrimaculata*
P. coccinellae (Schrank) — *Adalia bipunctata*, *A. decimpunctata*, *A. undecimpunctata*, *A. frigida*, *Adonia* sp., *A. undecimnotata*, *A. variegata*, *Anatis quinquedecimpunctata*, *Coccinella arcuata*, *C. divaricata*, *C. novemnotata*, *C. quinquepunctata*, *C. repanda*, *C. septempunctata*, *C. transversoguttata*, *C. trifasciata*, *C. undecimpunctata*, *Coccinellidae*, *Coelophora biplagiata*, *C. inaequalis*, *Coleomegilla maculata*, *Cycloneda munda*, *C. sanguinea*, *Epilachna quatuordecimnotata*, *Halyzia quatuordecimguttata*, (= *sedecimguttata*), *H. quatuordecimpunctata*, *Harmonia conglobata*, *H. quadripunctata*, *H. quatuordecimpunctata*, *Hippodamia convergens*, *H. glacialis*, *H. parenthesis*, *H. quinquesignata*, *H. sinuata*, *H. transversoguttata*, *H. tredecimpunctata*, *Leis dimidiata*, *Macronaemia hauseri*, *Olla abdominalis*, *Propylea quadridecimpunctata*, *Psyllobora vigintiduopunctata*, *Semiadalia undecimnotata*, *Verania discolor*
P. stuardoi Porter — *Adalia bipunctata*, *A.*

deficiens, *Eriopsis connexa*, *Cryptolaemus montrouzieri*

Synaldis sp. — *Epilachna varivestis*

Unidentified Braconidae — *Leis conformis*

Ceraphronidae

Aphanogmus sp. — *Chilocorus bipustulatus*

Chalcididae

Brachymeria sp. — *Epilachna chrysomelina*

B. carinatifrons Gahan — *Epilachna defecta*, *E. varivestis*

Unidentified Chalcididae — *Epilachna vigintioctopunctata*

Encyrtidae

Achrysopophagus aegypticus Mercet — *Chilocorus bipustulatus*

Anisotylus sp. — Coccinellidae, *Hyperaspis* sp., *Scymnus* sp.

A. albifrons Ishii — *Scymnus* sp.

A. similis similis (Ashmead)* — *Scymnus cervicolis*

A. similis texanus Timberlake — Coccinellidae, *Hyperaspis bigeminata*

A. similis utahensis Timberlake — *Scymnus americanus*, *S. collaris*, *S. lacustris*, *S. melshiemeri*

Homalotyloides laticapes Mali — *Chilocorus bipustulatus*

Homalotylus sp. — *Adalia flavomaculata*, *Adonia* sp., *Chilocorus* sp., *C. bipustulatus*, *Chilomenes* sp., *C. lunata*, *Coccinella* sp., *C. septempunctata*, Coccinellidae, *Cycloneda sanguinea*, *Cydonia* sp., *Exochomus* sp., *E. nigrimaculata*, *E. quadripustulatus*, *Hippodamia* sp., *Hyperaspis* sp., *H. guttulata*, *H. lateralis*, *Nephus* sp., *Scymnus* sp., *Sidis* sp., *Vibidia* sp.

H. affinis Timberlake — *Hyperaspis osculans*

H. albitarsus Gahan — Coccinellidae

H. brevicauda Timberlake — *Scymnus* sp.

H. cockerelli Timberlake — *Hyperaspis trimaculata*, *H. vittigera*

H. flaminus Dalman* — *Adonia variegata*, *Chilocorus* sp., *C. bipustulatus*, *C. kuwanae*, *Chilomenes lunata*, *Coccinella brucki*, *C. quinquepunctata*, *C. repanda*, *C. septempunctata*, Coccinellidae, *Egleis kingi*, *Exochomus* sp., *E. flavipes*, *E. quadripustulatus*, *Harmonia conglobata*, *H. quatuordecimpunctata*, *Hippodamia tibialis*, *H. tredecimpunctata*, *Hyperaspis campestris*, *H. senegalensis*, *Orcus chalybaeus*, *O. janthinus*, *O. laferiti*, *O. nummularis*, *Rodalia cardinalis*, *Scymnus* sp., *S. ornatus*, *S. soudanensis*, *Thea vigintiduopunctata*, *Verania frenata*

H. hyperaspidius Timberlake — *Hyperaspis undulata*

H. oculatus Girault — *Scymnus bipunctatus*

H. quaylei Timberlake — *Scymnus* sp., *S. fenestratus*, *S. includens*, *S. quadrimaculata*, *S. suturalis*

H. terminalis californicus Girault* — *Adalia bipunctata*, *Chilomenes sexmaculata*, *Coccinella novemnotata*, *C. quinquepunctata*, *Hippodamia convergens*

H. terminalis terminalis (Say)* — *Anatis quinquepunctata*, *Chilocorus similis*, *Coccinella novemnotata*, Coccinellidae, *Coleomegilla* sp., *C. innotata*, *C. maculata*, *Cycloneda* sp., *C. munda*, *C. sanguinea*, *Hippodamia convergens*, *Neomysia pullata*, *Psyllobora vigintimaculata*, *Scymnus* sp., *S. lacustris*

H. vicinus Say — *Nephus vetustus*

Isodromus niger Ashmead — *Chilocorus similis*

Lepidaphycus bosqui Blanch — *Cycloneda sanguinea*, *Eriopsis connexa*

Mestocharis lividus Girault — *Epilachna vigintioctopunctata*

Ooencyrtus johnsoni (Howard) — Coccinellidae
Stomatoceras colliscutellum Girault — *Epilachna vigintioctopunctata*

Zeteticontus sp. — *Chilocorus bipustulatus*
Eulophidae

Pediobius epilachnae Rohwer* — *Epilachna* sp., *E. chrysomelina*, *E. philippinensis*, *E. varivestis*, *E. vigintioctopunctata*

P. mediopunctata Wtstn. — *Coccinella* sp.

P. foveolatus Crawford — *Epilachna* sp.

Syntomosphyrum taprobanes Wtstn. — *Scymnus* sp.

Tetrastichus sp. — *Adalia* sp., *Adonia variegata*, *Chilocorus* sp., *Chilomenes lunata*, *Coccinella* sp., *Epilachna* sp., *E. indica*, *Exochomus* sp., *Hyperaspis senegalensis*, *Nephus* sp., *Scymnus ornatus*, *S. soudanensis*, *Sidis* sp.

T. coccinellae Kurdjumov — *Adalia bipunctata*, *Calvia quatuordecimpunctata* (= *sedecimpunctata*), *Chilocorus bipustulatus*, *C. renipustulatus*, *Chilomenes sexmaculata*, *Coccinella quinquepunctata*, *C. septempunctata*, *C. undecimpunctata*, Coccinellidae, *Harmonia quatuordecimpunctata*, *Synharmonia conglobata*

T. epilachnae Giard* — *Adalia bipunctata*, *Chilocorus bipustulatus*, *Coccinella septempunctata*, *Epilachna* sp., *E. argus*, *E. chrysomelina*, *Exochomus flavipes*, *E. quadripustulatus*, *Subcoccinella vigintiquatropunctata*

T. melanis Burks — *Coccinella* sp., *C. quinquepunctata*, *C. quinquepunctata*

T. minutus (Howard)* — *Adalia bipunctata*, *Chilocorus similis*, *Coccinella* sp., Coccinellidae, *Cycloneda sanguinea*

T. neglectus Domenichini — *Chilocorus bijugus*, *C. bipustulatus*, *Coccinella septempunctata*, *Exochomus quadripustulatus*, *Scymnus subvillosus*

T. sempronius Erdoes — *Chilocorus bipustulatus*

T. thanasimi Ashmead*—*Chilocorus stigma*
T. tibialis (Ashmead)*—*Coccinella novemnotata*
T. ovulorum Laboulbene — *Epilachna chrysomelina*, *E. vigintioctopunctata*
 Eupelmidae
Anastatus disparis Ruschka — *Chilocorus bipustulatus*
Eupelmus sp. — *Chilocorus bipustulatus*
 Ichneumonidae
Unidentified Ichneumonidae — *Coccinella septempunctata*
 Proctotrupidae
Lygocerus sp. — *Chilocorus bipustulatus*, *Coccinella septempunctata*
Unidentified Proctotrupidae — *Epilachna admirabilis*
 Pteromalidae
Metastenus townsendi (Ashmead)*—*Azya lutipis*, *Hyperaspis* sp., *H. lateralis*, *H. senegalensis*, *H. undulata*, *Scymnus* sp., *S. guttulatus*, *S. lacustris*
Pachyneuron sp. — *Adonia variegata*, *Chilomenes lunata*, *Hippodamia tredecimpunctata*, *Hyperaspis senegalensis*, *Scymnus kiesewetteri*, *S. ornatus*, *S. soudanensis*
P. chilocori Domenichini — *Chilocorus bipustulatus*
P. siphonophorae (Ashmead)* — *Hippodamia tibialis*, *H. tredecimpunctata*
P. syrphi (Ashmead) — *Coccinella septempunctata*
Pseudocatalaccus sp. — *Chilocorus bipustulatus*
Scymnophagus (= *Metastenus*) *mesnili* Farriere — *Pullus impexus*
Tripolycystus cryptognathae Girault — *Cryptognatha nodiceps*

Unidentified Pteromalid — *Hyperaspis lateralis*
Unidentified Parasite — *Chilomenes sexmaculata*, *Olla abdominalis*

SYNONYMY PARASITES

Anisotylus similis similis (Ashmead) (HEN) — *Homalotylus similis*
Homalotylus flaminus Dalman (HEN) — *Homalotylus flaminus*, *Homalotylus flaminus*
Homalotylus terminalis californicus Girault (HEN) — *Homalotylus obscurus* var. *californicus*, *Homalotylus terminalis*
Homalotylus terminalis terminalis (Say) (HEN) — *Eutelus scymnae* Shimer, *Homalotylus terminalis*, *Homalotylus obscurus*, *H. scymni*, *H. terminalis*
Metastenus townsendi (Ashmead) (HPT) — *Scymnophagus secundus*, *S. townsendi*, *Xenocrepis mexicana*
Pachyneuron siphonophorae (Ashmead) (HPT) — *Pachyneuron aphidiorum*
Pediobius epilachnae Rohwer (HEU) — *Pleurotropis epilachnae*
Tetrastichus epilachnae Giard (HEU) — *Lygellus epilachnae*, *Tetrastichus jablonowski*
Tetrastichus minutus (Howard) (HEU) — *Epomphaloides minutus*, *Syntomosphyrum esurus*, *Tetrastichus blephyri*, *T. blephyria*, *Tetrastichodes detrimmentosus*
T. thanasimi Ashmead (HEU) — *Tetrastichodes thanasimi*
T. tibialis (Ashmead) (HEU) — *Tetrastichodes tibialis*

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DRIFT PERIODICITY AND UPSTREAM DISPERSION OF STREAM INSECTS¹

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ABSTRACT

Drift periodicity and upstream dispersion by larval and nymphal insects from two north Idaho streams were investigated. Drift was determined with drift nets sampling at 2-hour intervals over 24-hour periods. Upstream dispersion was evaluated using a marking-release-recapture technique. Mayflies demonstrated nocturnal drift as did the corixid *Sigara* (*Vermicorixa*) *grossolineata* Hungerford and dipteran *Simulium* sp.; chironomids showed continuous drift as opposed to behavioral drift for most of the other insects studied. Both nocturnal and diurnal drift occurred with species in the order Trichoptera. Stoneflies showed little tendency to drift. Mid-summer upstream dispersion by mature nymphs and larvae of selected species was found to be insignificant as a means of recolonizing insect-decimated riffle habitats and offsetting downstream displacement by drift.

INTRODUCTION

Knowledge of recolonization processes of insect-decimated streams is a matter of increasing importance in understanding stream ecology. The presence or absence of certain species of insects often reflects the quality of a stream. Insects also constitute an important trophic link in food chains and play an important role in secondary production. Maintenance of unpolluted, high-quality streams and rehabilitation of those that have been rendered unproductive are vital considerations in stream management.

Population dynamics of stream insects, particularly dispersion by drift, has been investigated by Anderson (1967), Elliot (1967), Müller (1954), Pearson (1968), Waters (1962, 1968) and others.

Upstream dispersion of benthic invertebrates has been studied to a much lesser extent. Neave (1930) reported nymphs of the mayfly *Blasturus cupidus* Say to annually move up newly formed tributaries. Studying energy flow in a stream, Ball *et al.* (1963) detected upstream dispersion of radiophosphorus and suggested it was possibly transported by invertebrates. Bishop and Bishop (1968) reported no upstream movement of nymphs labeled with P³². Studying dispersal patterns of the mayfly nymph, *Baetis* sp. and a crustacean, *Gammarus* sp., Waters (1965) concluded that major movements in an experimental enclosure occurred in a downstream direction and at night, but did not exclude the possibility of some upstream movement. Roos (1967) reported the flight of egg-bearing, adult insects was principally upstream.

MATERIALS AND METHODS

Downstream dispersion by drift was studied

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during 1966 and 1967 in Merry Creek and Gold Center Creek respectively. Both creeks are principal tributaries of the St. Maries River in northern Idaho and are physically similar, having bottom types of cobble. They course through mountains of moderate relief and carry a light to moderate sediment load during spring run-off as a result of logging and road construction. The flow for Merry Creek was 14.32 and 10.35 ft³/sec during June and July respectively and 27.82 and 15.33 ft³/sec during the same months for Gold Center Creek. A single riffle from each creek was selected for study. The Merry Creek riffle, more appropriately classified a riffle-run, encompasses approximately 7.5 yards by 43 yards. The larger Gold Center Creek riffle has dimensions of 11 by 86 yards.

Drift insects were collected in two, square-foot drift nets, placed approximately 1 foot apart, in mid-channel. The collecting bags were 3-feet long and made of fine nylon (32 x 32 threads/inch). Samples were taken at 2-hour intervals over 24-hour periods during June 27 and July 29, 1966 from Merry Creek and June 29 and July 26, 1967 from Gold Center Creek. August samples were taken from each stream, but data were not summarized because of extremely low numbers of insects during that period.

The standing crop was measured with a 1-square-foot, cylindrical-bottom sampler similar to that described by Waters and Knapp (1961). The collecting bag was made of nylon, similar to that of the drift nets. Samples were taken along each side and through the middle of the riffle in order to reflect spatial distribution. Samples were taken above the position of the drift nets and subsequent to drift collections. Drift and bottom samples were stored in 70% alcohol. Insects were sorted by hand, identified and counted. Quantitative enumerations for drift and standing crop are given as numbers per unit time and per unit area respectively.

Determination of upstream dispersion by insects in water was made through use of a marking-release-recapture technique. Fluorescent pigments described by Brusven (1970) were used for marking insects. Two channelettes (Streams I and II) off the St. Maries River and Gold Center Creek were used for the study. They ranged from 4-7 feet wide and supported a 3-6 inch water column during most of the summer; bottom types were pebble and cobble. Insects were collected 20 feet above and 40 feet below the release zone by turning and scraping the bottom materials to simulate a relatively insect-free area that might occur as a result of extreme scouring. Insects used for marking were captured with a standard 3-foot aquatic screen from the channelettes and augmented with insects from the larger adjoining streams. To facilitate handling and recovery, only

larger specimens of immature Ephemeroptera, Trichoptera and Plecoptera were used for marking. The latter was emphasized because the large size of several species of stoneflies made them excellent subjects for release and recapture. Marked releases were made on the basis of availability, so no attempt was made to unify release numbers during each of the release periods of June, July and August.

Insects collected for marking were segregated, counted and placed in partially submerged 3 x 3 x 5 inch screened cages. The cages were momentarily lifted from the water; insects were uniformly fogged with fluorescent powder, then submerged several times to remove excess powder. Marked insects were introduced into a 3-foot release zone in each stream. A screen was placed immediately below the release zone to catch insects that did not become established with the bottom; the screen was not removed until all insects had become established. Recaptures were again made with a standard aquatic collecting screen by turning and scraping the bottom sediments after a 48-hour period, thus encompassing two dark-light periods. A complete sampling of an area 18 feet above and 42 feet below the release zone was made.

RESULTS

Drift Periodicity

Drift was determined for the principal riffle insects occurring in Merry and Gold Center Creeks (Fig. 1-4). Standing crop and daily drift are given in Tables 1 and 2 for the principal species in the orders Ephemeroptera, Plecoptera, Hemiptera, Trichoptera and Diptera. With the exception of riffle beetles (Elmidae), coleopterans were poorly represented in the study.

Ephemeroptera

Mayflies were the most abundant insects from the two streams studied. Nine genera and 18 species were collected in drift and/or bottom samples during the study with *Baetis* and *Ephemerella* the principal genera. As a group, mayflies demonstrated nocturnal drift (Fig. 1a,c). June drift was appreciably higher than July drift and is consistent with a decrease in standing crop between the two months. *Baetis bicaudatus* Dodds, *Ephemerella edmundsi* Allen, *E. inermis* Eaton, *E. tibialis* McDunnough and *E. flavilinea* McDunnough each demonstrated a single drift peak between 10 p.m. to 2 a.m. (Fig. 1b,d; 2c-f). *Baetis tricaudatus* Dodds, reflected a bimodal drift pattern with two peaks occurring during the dark hours (Fig. 2a,b). It is significant to note that the pattern exhibited by this species occurred during July from two different streams, during two different years.

Plecoptera

Stoneflies, although abundant benthic in-

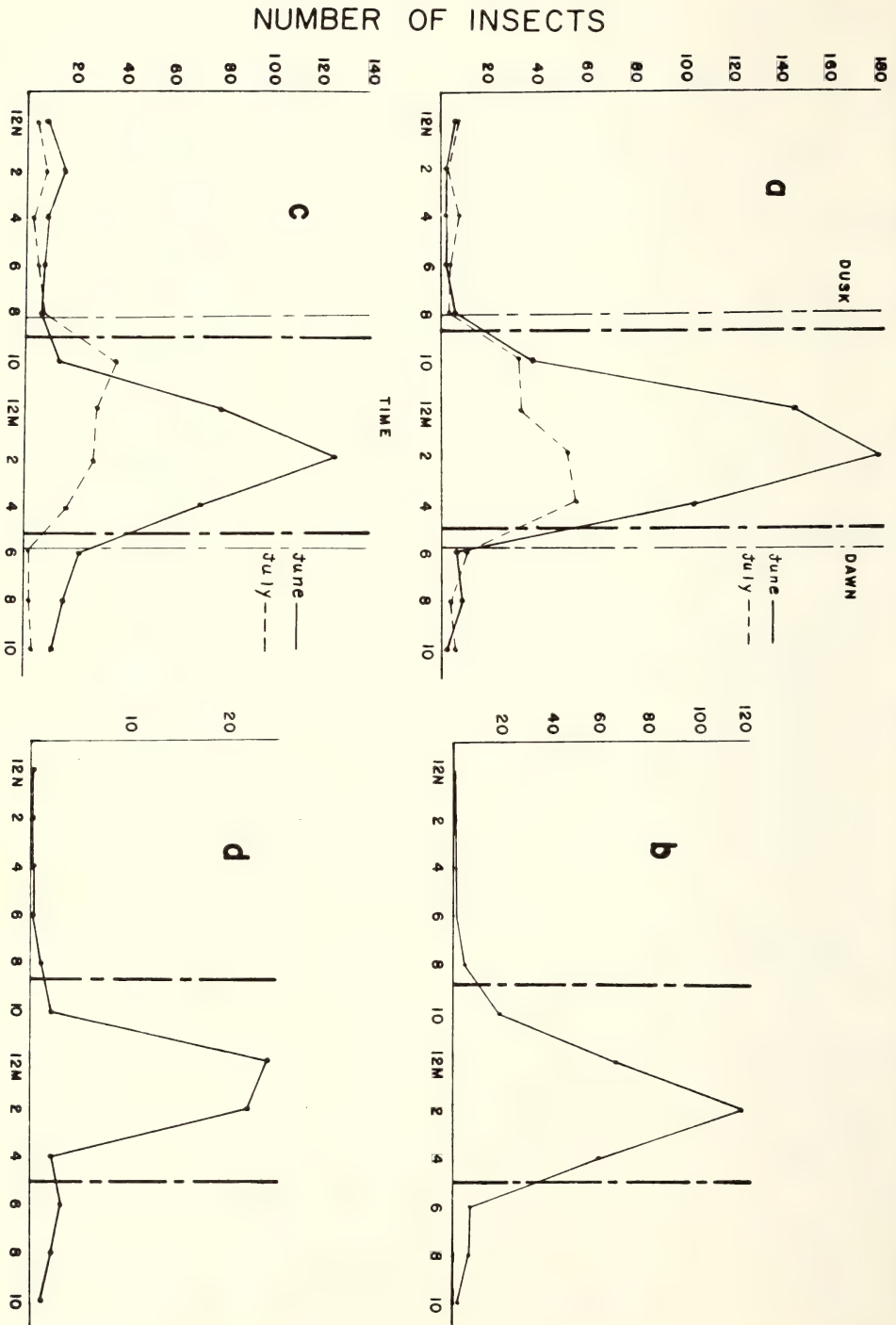


Fig. 1. Drift rate/2 nets/2-hour intervals for: a. Ephemeroptera (total drift), Merry Creek, 1966; b. *Ephemerella tibialis* McDunnough, Merry Creek, June 27, 1966; c. Ephemeroptera (total drift), Gold Center Creek, 1967; d. *E. flavilinea* McDunnough, June 29, 1967.

NUMBER OF INSECTS

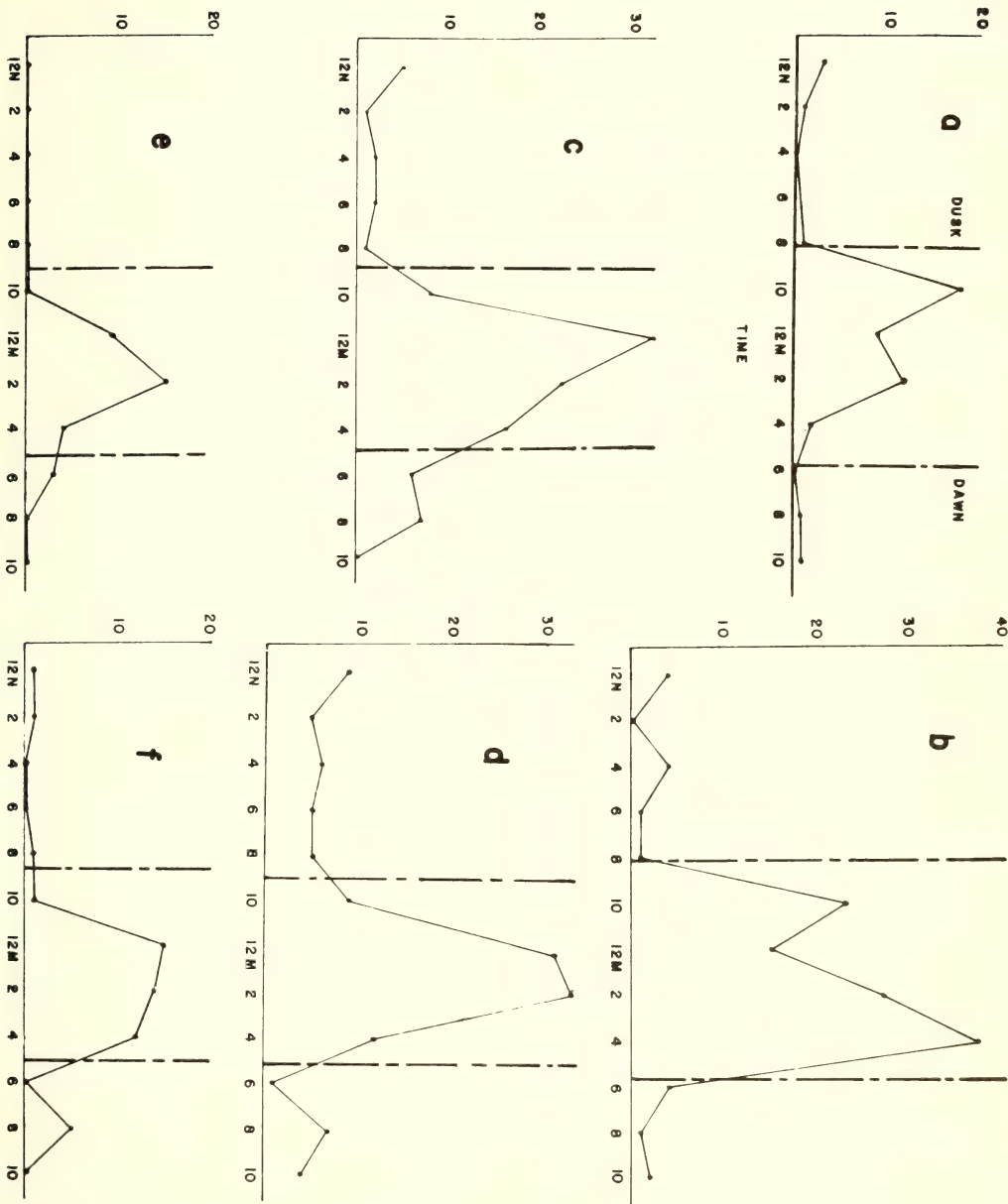


Fig. 2. Drift rate/2 nets/2-hour intervals for: a. *Baetis tricaudatus* Dodds, Gold Center Creek, July 26, 1967; b. *B. tricaudatus* Dodds, Merry Creek, July 29, 1966; c. *B. bicaudatus* Dodds, Merry Creek, June 27, 1966; d. *B. bicaudatus* Dodds, Gold Center Creek, June 29, 1967; e. *Ephemerella edmundsi* Allen, Gold Center Creek, June 29, 1967; f. *E. inermis* Eaton, Gold Center Creek, June 29, 1967.

vertebrates, were poorly represented in drift (Tables 1 and 2). With the exception of *Alloperla* sp. which showed a slight increase in drift at night, no drift trends were evident. Anderson and Lehmkuhl (1968) reported small stoneflies *Capnia* sp. and *Nemoura* sp. as important drift components after the first freshet in November. With the exception of *Alloperla* sp. which is relatively small, the stoneflies *Isogenus*, *Acroneuria* and *Pteronarcys* occurring in this study are medium to large size as mature nymphs and exhibit extreme mobility. It is believed their physical strength and swimming abilities better enable them to counteract the effects of current and are not easily displaced.

Hemiptera

The corixid bug, *Sigara (Vermicorixa) grossolineata* Hungerford, was an unexpected drift invertebrate. It occurred from both Merry Creek and Gold Center Creek and reflected a precipitous increase in drift after dark (Fig. 3a-c). No specimens were taken in drift during the daylight hours from Merry Creek and only an occasional specimen from Gold Center Creek. Waters (1962) reported essentially similar results for the corixid *Hesperocorixa* sp.

All corixids recovered in drift were adults. It is probable their occurrence in drift was the result of an evening flight originating from some other point along the stream since they were not recovered in bottom samples from the two riffles investigated.

Diptera

Diptera larvae were well represented in bottom samples, but with the exception of chironomids and simuliids, showed little tendency to drift (Tables 1 and 2). Collectively, chironomids showed continuous drift during the day (Fig. 3e). Although there were detectable differences among 2-hour sampling periods, there was no indication of a day- or night-active period. The standing crop decreased by a factor of 2 between June and July while there was a 17-fold increase in drift. This increase occurred commensurate with a decrease in stream discharge. Anderson and Lehmkuhl (1968), however, reported an increase in chironomid drift as stream discharge increased.

Simulium sp. drift from Merry Creek during July indicated a night-active period (Fig. 3d), reaching highest proportions at midnight. A direct relationship appears to exist between standing crop and drift (Table 1). No larvae were collected in bottom samples in June and only four individuals were collected in drift. During July, there was a noticeable increase in bottom density to 6.41 larvae per sq. yd. and a daily drift of 86 individuals.

Trichoptera

As a group, caddisflies demonstrated highly

variable drift patterns (Fig. 4). The brachycentrid genera of *Micrasema* and *Brachycentrus* reflected a precipitous increase in drift after sunset, reaching highest levels at midnight; a much smaller, secondary drift period occurred during early morning (Fig. 4a,d). Because of the diminutive nature of the secondary peak, particularly by *Brachycentrus*, it might be questioned whether this was indeed a "bigeminus" drift pattern, i.e. the major peak occurs first and shortly after sunset, followed by a secondary peak, as discussed by Müller (1965).

Drift by the limnephilid *Dicosmoecus gilvipes* (?) (Hagen) reflected a day active or more appropriately an afternoon-active period, occurring between 10 a.m. to 8 p.m. (Fig. 4b). Drift decreased after sunset and remained low until 10 a.m. the following morning. Continued low drift during the daylight hours of the subsequent morning suggests this species was both light and temperature sensitive. The daily temperature range for June 29, 1967 was seven degrees F., being highest at 4 p.m. and lowest at 4 a.m. Most of the larvae taken in drift were caseless, indicating they were perhaps in the process of reconstructing new cases. It is interesting to note that the *Dicosmoecus* sp. population from Merry Creek did not show similar drift tendencies, although the bottom density was higher than Gold Center Creek. The bottom density of *Dicosmoecus gilvipes* (?) in Gold Center Creek was not appreciably different between June and July, however, considerable differences in daily drift were recorded (Table 2). This is probably the result of age-behavioral changes or age-distributional changes as suggested by Anderson (1967).

The lepidostomatid trichopteran, *Lepidostoma* sp., demonstrated a relatively high tendency to drift as reflected by the relationship of bottom density to daily drift during June from Gold Center Creek (Table 2). Slightly higher drift occurred during the daylight hours, decreasing to lowest levels at 2 a.m. (Fig. 4c). Anderson (1967) reported *L. unicolor* (Banks) having no discernible daily drift periodicity.

Arctopsyche grandis (Banks), a net-spinning trichopteran, drifted most actively at night from Gold Center Creek. *Hydropsyche* sp. from Merry Creek, another member of the hydropsychid family, showed little tendency to drift, although its density was approximately twice that of *Arctopsyche* from Gold Center Creek (Tables 1 and 2). Few members of either genus were taken by drift or bottom samples from either creek during July and is probably the result of pupation and emergence as indicated by adult collection records.

Upstream Dispersion

Upstream dispersion by larval and nymphal insects was investigated to determine if it occurred in

NUMBER OF INSECTS

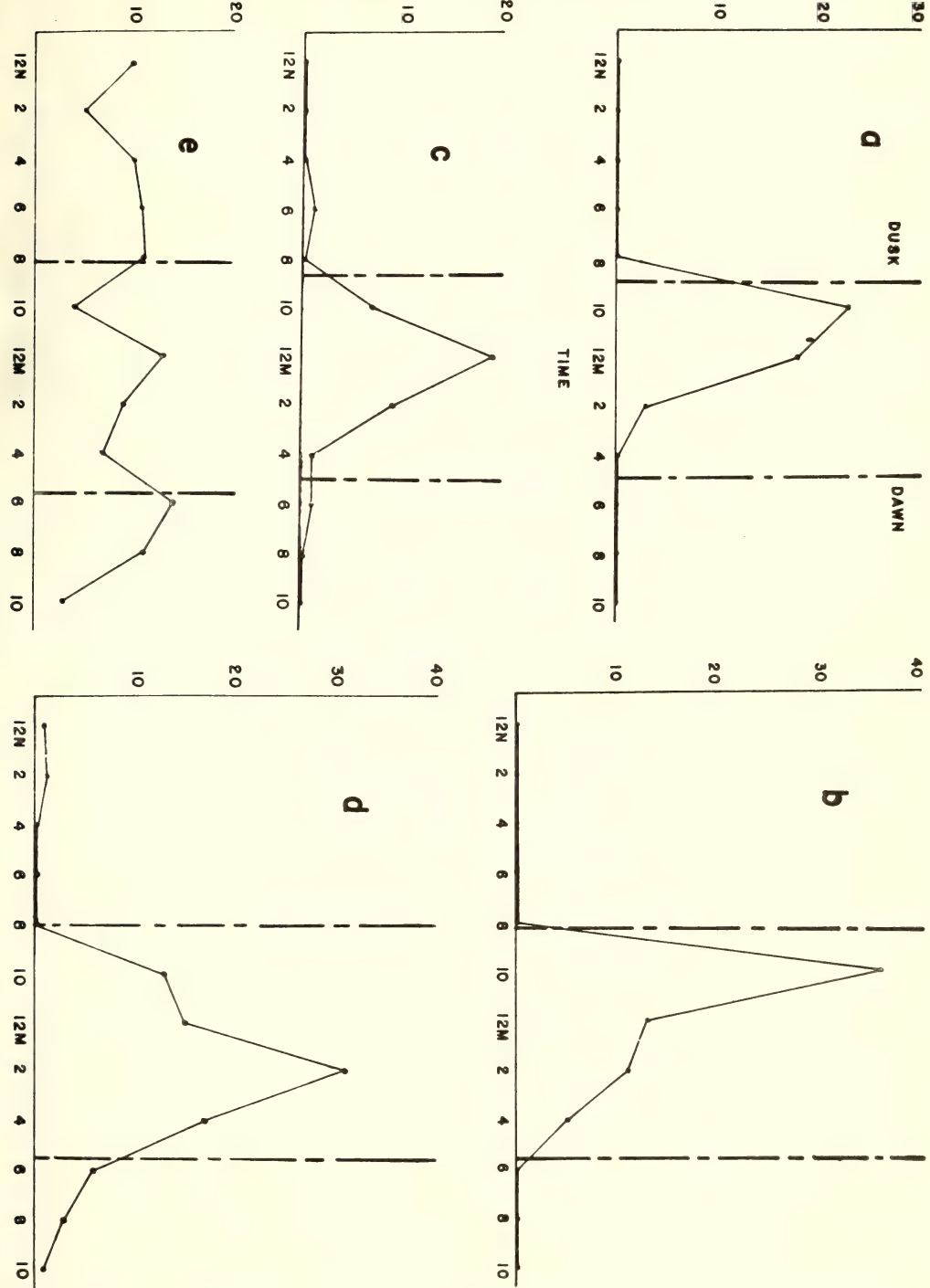


Fig. 3. Drift rate/2 nets/2-hour intervals for: a. *Sigara grossolineata* Hungerford, Merry Creek, June 27, 1966; b. *S. grossolineata* Hungerford, Merry Creek, July 29, 1966; c. *S. grossolineata* Hungerford, Gold Center Creek, June 29, 1967; d. *Simulium* sp., Merry Creek, July 29, 1966; e. Chironomidae, Merry Creek, July 29, 1966.

streams and what role it played in offsetting downstream displacement by drift. The number and kinds of insects marked and released are given in Table 2. Marked releases were made in June, July and August in Stream II, but only during June and July in Stream I because of low flow during August. Streams were sampled 48 hours after the insects were released in order to determine distribution of marked insects in relation to their point of release (Tables 4 and 5).

No marked insects were recovered above the release area in Stream I; only two insects, representing 4.9% of the total recovered insects in Stream II, were collected above the release zone. The latter were taken in the first 3-foot region above the point of release. Highest recovery of marked insects was from the release zone, although the area was small in relation to the collective upstream and downstream areas sampled (Tables 4 and 5). Recovery of marked insects from Stream I during June and July was 13.3 and 7.2% respectively; recovery from Stream II was 6.7, 8.6 and 33.7% for the months of June, July and August respectively. The current velocities for these same periods were 0.8 and 0.5 ft/sec in Stream I and 1.1, 0.9 and 0.5 ft/sec for Stream II.

DISCUSSION

Drift

Insect drift, manifesting distinct periodicities, was a common phenomenon in both streams studied. These periodicities suggested a circadian rhythm entrained by exogenous factors as light and to a lesser degree temperature. The periodicity of drift varied considerably both between and within insect orders (Fig. 1-4). Most insects showed behavioral drift, a notable exception was chironomids which demonstrated relatively constant drift (Fig. 3e). Mayflies as a group reflected nocturnal drift, as did the hemipteran *Sigara (Vermicorixa) grossolineata* Hungerford, dipteran *Simulium* sp., and trichopterans *Micrasema bactro* Ross, *Brachycentrus* sp. and *Arctopsyche grandis* (Banks) (Fig. 1-4). The limnephilid trichopteran *Dicosmoecus gilvipes* (?) (Hagen) differed from other insects studied in that an afternoon-active drift period (Fig. 4b) was indicated, which was probably the result of sensitivity to both light and temperature. The trichopteran, *Lepidostoma* sp. reflected a weak day-active drift period (Fig. 4a). Stoneflies were not a significant component of drift although their density was comparable to several other drift insects.

Because of the open-ended nature of lotic habitats and the possibility of long-distance displacement of stream insects, it is difficult to unequivocally relate benthic density to drift. Temporal and interstream

comparisons are further complicated by differing physical and biotic parameters. The physical conditions of riffle or stream size, substrate type and current velocity are undoubtedly important factors influencing the magnitude of drift. Drift in this study is expressed as a rate, i.e. number of organisms drifting per unit stream width per unit time. Elliott (1967) partially overcame the difficulty of expressing drift under different flow regimes by expressing it as density units, i.e. number of organisms per unit volume of water.

Age-distribution and age-behavioral differences are important biotic factors influencing drift (Anderson, 1967). The latter was indicated by the trichopteran *Dicosmoecus gilvipes* (?) in this study (Table 2). Density may also be a factor in changing the propensity of drift as indicated by Pearson and Franklin (1968). The generally low population densities from Merry Creek and Gold Center Creek, however, did not permit a critical evaluation of this factor.

That drift indeed exists for many stream insects, often in a large and spectacular way, was borne out in this study (Fig. 1-4; Tables 1-2). However, neither distances of displacement nor the physical hazards experienced by drifting insects are well established. A complete understanding of the implications of drift on the stream community cannot be fully assessed until such information becomes available.

Upstream Dispersion

Upstream dispersion, as a means of offsetting displacement by drift, was determined to be insignificant for late-instar nymphs and larvae of species studied (Tables 4 and 5). Although a nearly insect-free region was created above the release zone by removing insects prior to releasing marked insects, there was no indication of significant upstream movement into available niches. Use of blocking devices in the test channellets were avoided in order to refrain from interference with normal flow characteristics of the stream, thus, marked and unmarked insects were free to enter and depart from test areas. Recovery data are reflective on a relative basis since complete recovery of marked insects was not obtained nor expected (Table 3-5). A significant part of the marked population undoubtedly became a product of drift and was displaced to lower reaches of the stream.

The stoneflies, *Pteronarcys californica* Newport and *Acronuria* sp., being large in size and mobile, were emphasized in this study and proved to be effective test insects. Larger mayflies *Ephemerella hecuba* (Eaton), *E. grandis* Eaton and *E. doddsi* Needham were nearly as effective but occurred in low numbers in the study area. The caddisflies, *Arctopsyche grandis* (Banks) and *Hydropsyche* sp.

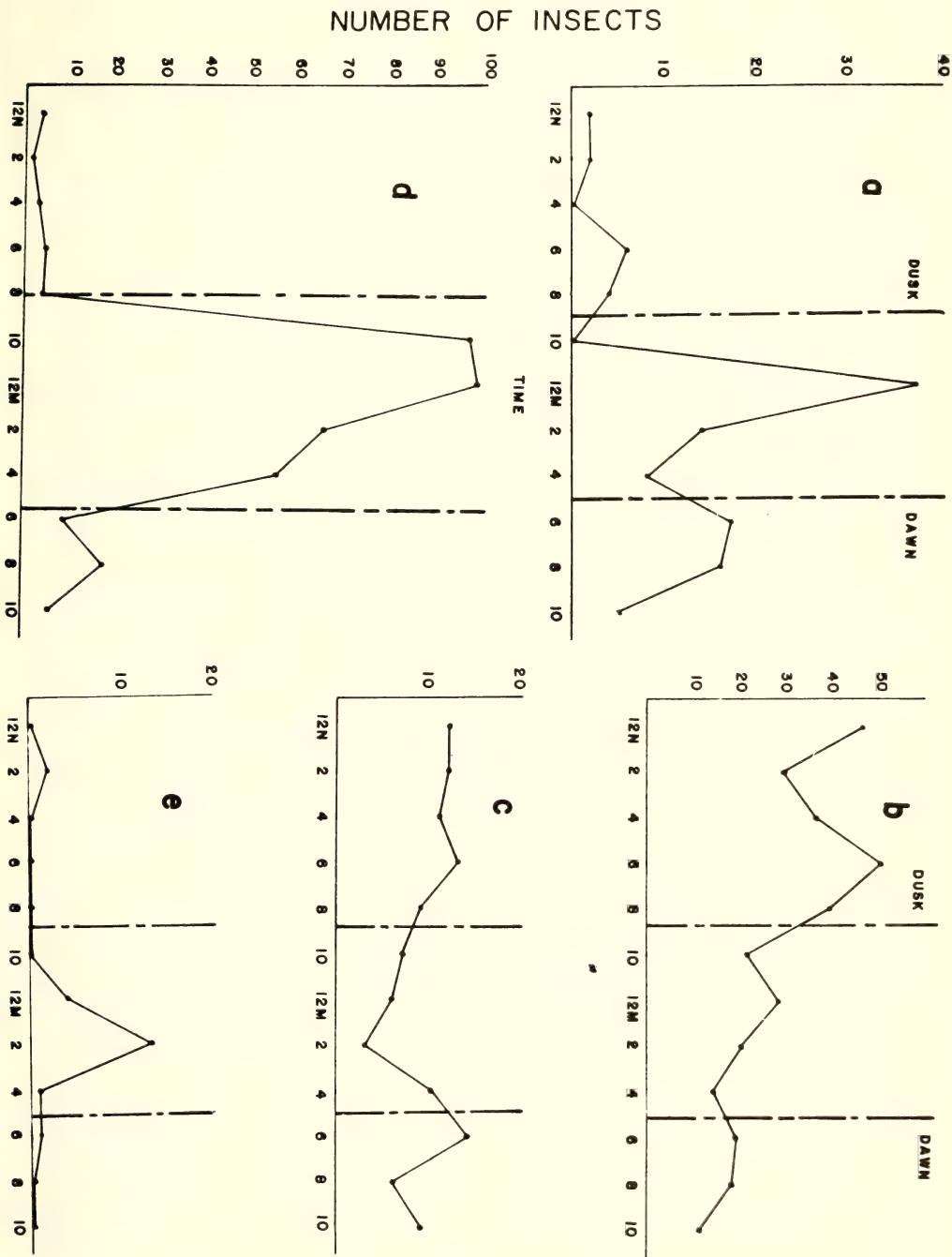


Fig. 4. Drift rate/2 nets/2-hour intervals for: a. *Micrasema bactro* Ross, Merry Creek, June 27, 1966; b. *Dicosmoecus gilvipes* (?) (Hagen), Gold Center Creek, June 29, 1967; c. *Lepidostoma* sp., Gold Center Creek, June 29, 1967; d. *Brachycentrus* sp., Merry Creek, July 29, 1966; e. *Arctopsyche grandis* (Banks), Gold Center Creek, June 29, 1967.

Table 1. Standing crop and daily drift of principal insects from Merry Creek during June and July, 1966.

INSECTS	June 27		July 29	
	No. per sq. yd.	Daily Drift per 2 nets	No. per sq. yd.	Daily Drift per 2 nets
Diptera				
Chironomidae	30.30	7	15.38	118
Rhagionidae (<u>Atherix</u> sp.)	4.54	4	15.38	1
Tipulidae	4.54	2	25.64	0
Simuliidae (<u>Simulium</u> sp.)	0	4	6.41	86
Ephemeroptera				
<u>Baetis bicaudatus</u> Dodds	9.09	102	11.54	1
<u>Baetis tricaudatus</u> Dodds	18.18	14	39.74	125
<u>Epeorus longimanus</u> (Eaton)	51.52	8	1.28	0
<u>Ephemerella flavilinea</u>				
McDunnough	40.91	28	0	0
<u>Ephemerella inermis</u> Eaton	53.03	2	0	0
<u>Ephemerella tibialis</u>				
McDunnough	2.08	285	141.02	35
<u>Rhithrogena</u> sp.	87.87	11	0	0
Plecoptera				
<u>Alloperla</u> sp.	7.58	11	2.56	6
<u>Isogenus</u> sp.	7.58	5	0	1
<u>Pteronarcys californica</u>				
Newport	1.52	0	0	6
Trichoptera				
<u>Brachycentrus</u> sp.	13.64	17	19.23	363
<u>Dicosmoecus</u> sp.	19.70	13	5.13	0
<u>Hydropsyche</u> sp.	6.06	3	0	0
<u>Micrasema bactro</u> Ross	3.03	111	14.10	3
<u>Rhyacophila</u> sp.	3.03	0	3.85	0

occurred abundantly but were difficult to sample. Highest recovery of marked insects was obtained for stoneflies as would be expected on the basis of numbers released (Tables 3-5). A reasonably high recovery of *Ephemerella grandis* was obtained in the release zone or slightly below, although the number marked and released was small in comparison with the stoneflies *P. californica* and *Acroneuria* sp. An interesting recovery trend was observed in Stream II; the percentage recovery of marked insects increased progressively from 6.7% to 33.7% between June and August commensurate with a decrease in stream velocity from 1.1 to 0.5 ft/sec during the same period. The lower velocity of 0.5 ft sec probably better enabled the insects to maintain contact with the cobble substrate. Similar recovery trends in Stream I were not evident although there was a decrease in flow between June and July; the

channel was nearly dry in August. The bottom was pebble in Stream I as opposed to cobble in Stream II and was generally a less favorable habitat for stoneflies and caddisflies. Stoneflies generally reflected reasonably high fidelity for the site or slightly below the site in which they were released. This was dramatically in evidence during August in Stream II when 34% of the stoneflies marked and released were recovered in the 3-foot release zone (Table 5). Caddisfly recovery, particularly hydropsychid caddisflies, was generally low during all test periods from both streams. This was probably the result of their net-spinning habits, making them less vulnerable to recapture or they were rapidly displaced as drift. In general, the incidence of recovery of marked insects per unit area became less as the distance from the release zone increased.

Insect recolonization is a matter of considerable

Table 2. Standing crop and daily drift of principal insects from Gold Center Creek during June and July, 1967.

INSECTS	June 29		July 26	
	No. per sq. yd.	Daily Drift per 2 nets	No. per sq. yd.	Daily Drift per 2 nets
Diptera				
Rhagionidae (<u>Atherix</u> sp.)	3.76	3	18.00	5
Tipulidae	2.25	11	2.50	2
Simuliidae (<u>Simulium</u> sp.)	0	28	0	4
Ephemeroptera				
<u>Baetis bicaudatus</u> Dodds	7.52	127	1.50	28
<u>Baetis tricaudatus</u> Dodds	.75	20	2.50	48
<u>Cinygmula</u> sp.	12.78	11	6.50	4
<u>Epeorus longimanus</u> (Eaton)	3.00	35	3.50	13
<u>Ephemerella flavilinea</u> McDunnough	9.77	57	1.50	3
<u>Ephemerella inermis</u> Eaton	10.53	50	0	0
<u>Ephemerella tibialis</u> McDunnough	0	16	20.50	49
<u>Rhithrogena hageni</u> Eaton	4.51	17	0	0
Plecoptera				
<u>Acroneuria</u> sp.	3.76	1	2.50	1
<u>Alloperla</u> sp.	3.76	8	29.00	18
<u>Isogenus</u> sp.	5.26	4	1.00	3
<u>Pteronarcys californica</u> Newport	1.50	0	2.00	0
Trichoptera				
<u>Dicosmoecus gilvipes</u> (?) (Hagen)	6.76	331	4.50	8
<u>Hydropsyche</u> sp.	3.75	6	3.00	7
<u>Lepidostoma</u> sp.	1.50	112	0	5
<u>Micrasema bactro</u> Ross	0	9	0.50	0
<u>Arctopsyche grandis</u> (Banks)	3.00	21	0.50	9

Table 3. Number of insects marked and released in Streams I and II in northern Idaho, 1967.

Insect Species	JUNE		JULY		AUGUST	
	Stream I	Stream II	Stream I	Stream II	Stream I	Stream II
Plecoptera						
<u>Pteronarcys californica</u>	2	1		28		14
Newport						
<u>Acroneuria</u> sp.	10	14	20	40		53
Trichoptera						
<u>Arctopsyche grandis</u> (Banks)		13	51	20		14
<u>Hydropsyche</u> sp.		7	6	5		
<u>Limnephilidae</u> (spp. unid.)		8	8			
Ephemeroptera						
<u>Ephemerella hecuba</u> (Eaton)						6
<u>Ephemerella grandis</u> Eaton	10	2	8			
<u>Ephemerella doddsi</u> Needham						2
<u>Ephemerella flavilinea</u> McDunnough	6		4			
<u>Rhithrogena</u> sp.	2					
TOTAL	30	45	97	93	0	89

importance in studying the ecology of streams. Downstream displacement by drift is perhaps the most prolific and viable means of colonization. Upstream dispersion by adults is largely conjectural and untested for most stream insects, although Roos (1957) reported this phenomenon for caddisflies. Upstream dispersion by nymphs and larvae was proven insignificant for the species investigated in this study. It is probable, barring catastrophic events, that most reaches of a stream support a residual population of sufficient size to assure perpetuation, irrespective of drift or upstream movements. However, the previously mentioned means of dispersion can function independently or collectively to hasten recolonization of an insect-

decimated area or to mitigate extreme population fluctuations of any given stream habitat such as a riffle or pool.

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Table 4. Numbers and species of insects recaptured after 48-hour period from Stream I.

Distance (Feet)		June 29	July 26
Above Release Zone	12 - 18	0	0
	6 - 12	0	0
	3 - 6	0	0
	0 - 3	0	0
3-Foot Release Zone		1F	1A, 1B, 1D
Below Release Zone	0 - 3	0	1D
	3 - 6	1C, 1F	1C
	6 - 12	0	0
	12 - 18	0	0
	18 - 24	1F	0
	24 - 30	0	0
	30 - 36	0	0
	36 - 42	0	1E, 1A
Trichoptera		Plecoptera	Ephemeroptera
A. <u>Arctopsyche</u> sp.		D. <u>Acroneuria</u>	E. <u>Ephemerella</u> <u>flavilinea</u>
B. <u>Hydropsyche</u> sp.		sp.	McDunnough
C. <u>Limnephilidae</u> (spp. unid.)			F. <u>Ephemerella</u> <u>grandis</u> Eaton

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Table 5. Numbers and species of insects recaptured after 48-hour period from Stream II.

Distance (Feet)		June 29	July 26	August 25
Above Release Zone	12 -18	0	0	0
	6 - 12	0	0	0
	3 - 6	0	0	0
	0 - 3	0	1C	1D
3-Foot Release Zone		2B, 1C	4C	1A, 6C, 17D, 1E
Below Release Zone	0 - 3	0	1C	1C, 1A
	3 - 6	0	0	1D
	6 - 12	0	0	0
	12 - 18	0	1D	0
	18 - 24	0	1C	1C
	24 - 30	0	0	0
	30 - 36	0	0	0
	36 - 42	0	0	0
Ephemeroptera		Plecoptera		Trichoptera
A. <u>Ephemerella</u> <u>hecuba</u> (Eaton)		C. <u>Pteronarcys</u> <u>californica</u>		E. <u>Arctopsyche</u>
B. <u>Ephemerella</u> <u>grandis</u> Eaton		Newport		sp.
		D. <u>Acroneuria</u> sp.		

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